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MOORE COUNTY, NORTH CAROLINA, METEORITE— A NEW EUCRITE

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INTRODUCTION

This meteorite fell April 21, 1913, at about 5:00 P.M., on the farm belonging to Mr. George C. Graves, located about 3 miles east of Carthage, Moore County, North Carolina, longitude $79^{\circ} 23' W.$, latitude $35^{\circ} 25' N.$ Mr. Graves had this specimen taken to his store in Carthage where it was displayed for several days and then it was given to his wife who has carefully preserved it and all records pertaining to the fall. The authors are indebted to Mrs. Graves for preservation of both the records of the fall and also the meteorite.

The day of the fall, April 21, 1913, was partly cloudy and partly rainy, the sun being hidden by fleecy clouds and no appreciable wind was blowing. The first warning of a meteorite was a roaring overhead to the southwest. The roar of the meteorite was heard by persons within a radius of about five or six miles from the location of the fall. The sound effect was described as rumbling and zooming with no distinct explosions.

The meteorite fell in an open freshly plowed field where Mr. Haig Cockman and two negro helpers were working a cotton crop. Looking overhead, Mr. Cockman and the negroes noted what they described as a red hot ball followed by a trail of blue-black smoke, estimated to be about 15 feet long. There were bright sparklers given off from this meteorite. The noise was heard before the meteorite was noted and became more audible as the meteorite approached, and even a slight rumbling persisted for a short interval after it struck the ground. It embedded itself in the soft plowed ground to a depth of about two feet and within a few feet of Mr. Cockman. The hole had a slight slope from the southwest, but appeared to be nearly vertical.

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PHYSICAL PROPERTIES OF MOORE COUNTY METEORITE

This meteorite is a very symmetrical individual stone weighing 4 lbs. 2 oz. and shows well developed flight markings. The maximum measurements taken in three directions, at right angles to each other, are $6" \times 4 \frac{3}{16}" \times 3 \frac{3}{16}"$. The meteorite was not a rotating body in its fall through the atmosphere. Its present flattened conical shape together with radial markings on the sloping sides is considered ample evidence of the fact that certainly through the last portion of its flight, and in the most dense atmosphere, it maintained a fixed orientation.

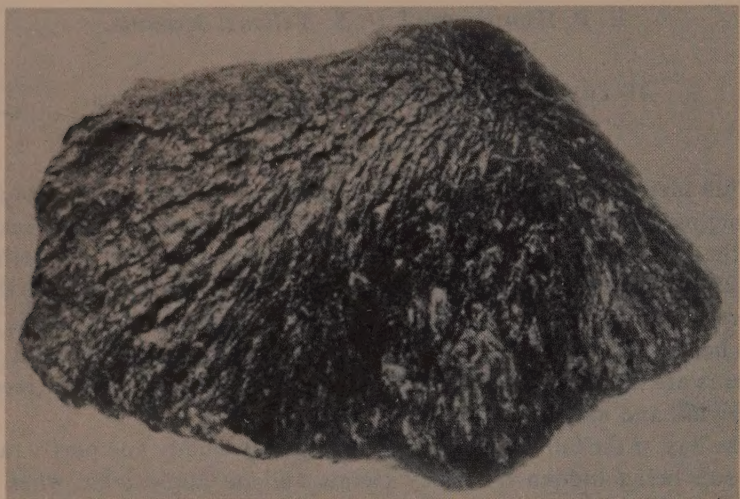


FIG. 1. Moore County, North Carolina, meteorite. The forward face showing flight markings.

The paths of meteors are generally straight, a fact which is supported both by crude visual observations and by photographic plates.¹

The surface is covered with a dark colored glassy brown material with shallow furrows (piezoglyphs) extending from the "brustseit" to the outer edges of the face which was forward on its oriented flight. At the crown or "brustseit" the glass is pitted with rounded irregular shallow depressions but on the sloping sides the furrows become very definite, at first they are shallow but farther down the sloping sides they become wider and deeper.

Other than these furrows the surface is almost free from any pitting. Near the outer edges of the forward face there are a few groove shaped depressions which have been carved out by the force of the air. These are

¹ Fisher W. J., *Harvard College Observatory Circular* 385.

considerably deeper than the furrows, the deepest of these measuring about 4 mm. The glass is very thinly spread over the forward face, in fact, so thin that the color of the component minerals of the meteorite can be seen through the glass. At all places where measurement was possible the thickness of the glass on this face is less than 1 mm. This indicates that as fast as the minerals were heated to their fusion point or to the temperature where they were slightly plastic, they were removed by the force of the rushing air. With such a high velocity, and consequent fusion, the size of this meteorite must have been rapidly reduced. Presumably most of the material is carried off in finely divided particles. Such particles trail behind to constitute the smoke train.

Fused material has cooled and collected on the rear face of this meteorite. Here it is too thick to be transparent, and it appears as a black glass. In this glass are conspicuous vesicular cavities. In the central portion of this face, where it is uniformly spread, the glass is about twice as thick as on the forward face. Near the rim of this rear face, just under the edges from the sloping front faces, there is a maximum accumulation of this glass. This maximum accumulation is an almost continuous band about 5 mm. thick and about 1.5 cm. wide.

This meteorite was cut into two almost equal parts and a slice was taken off one half to provide material for the detailed study of the minerals. Superficially this meteorite appeared to be free from fractures, but, after cutting, two rather prominent fractures were found. Both of these were completely concealed by the surface covering of glass and therefore it seems logical to assume that these fractures were in existence prior to the entrance of the meteorite into our atmosphere.

To the unaided eye there appeared to be present but three minerals: viz., white basic bytownite (near anorthite), yellow pyroxene, and a few very small and scattered inclusions of chromite. The former two constituents appeared to be present in about equal proportions. No free iron or sulphides could be seen, but subsequent chemical tests proved their presence.

GENERAL STRUCTURE OF THE METEORITE

The texture of the Moore County meteorite is best described as uniformly granular and unusually coarse grained for a meteorite. The minerals are uniformly distributed throughout the entire mass. There is very little bond between the component minerals. In fact the minerals can be easily separated by lightly rubbing the fingers over the surface from which the fused glassy covering has been removed. It was found to be almost impossible to make thin sections of this meteorite without causing the mineral grains to completely separate one from another.

The cleavage in the feldspar is developed far more perfectly than is normally the case and, in preparing the thin section, many of the laths of feldspar were broken into small cleavage fragments. When thin sections of terrestrial rocks are made the feldspars rarely shatter into cleavage fragments. There is also a tendency for the pyroxene minerals to separate into cleavage fragments, but to a lesser extent than the bytownite.

The development of the cleavage is a significant feature of this fall and may be connected with some of the thermal changes described later in this paper. However, the authors are not able to definitely state that this is true. The lack of bond between the mineral components may be due to the same cause which has developed the cleavages, although there is the possibility that it is more closely connected with the chemical composition of the meteorite. In the Moore County meteorite there is no excess of free silica (see Table 4) and it is very likely that quartz serves to some extent as a binder to the minerals with which it is associated in igneous rocks. Some dunites are equally as granular and friable as this meteorite and they are free from quartz.

Farrington² states that "all eucrites and shergottites show an ophitic structure." This Moore County meteorite can be classified as a eucrite since the feldspar is near anorthite in composition, but it certainly does not possess to any appreciable extent an ophitic texture.

The slice, used for the mineralogical study, was carefully washed with water to remove the abrasive agents used in cutting it from the meteorite. After washing it was dried in an oven at 110° for three hours to expel any absorbed moisture. The central portion was broken out, crushed and treated with heavy solutions to separate the mineral constituents. Since only the central portion was selected for study there is no possibility of including any of the fused outer portion, or minerals which may have been affected by the heating during its flight.

This meteorite, because of its coarse granular texture, afforded an excellent opportunity for a careful mineralogical study of the component minerals.

MINERALOGY

A solution of methylene iodide was adjusted so as to float the bytownite and drop the pyroxene. The bytownite was twice treated in this manner and then placed in a second solution of methylene iodide, adjusted to float off any mineral of lighter specific gravity, such as quartz or a lighter feldspar. This proved useless as none was found.

² *Meteorites, their Structure, Composition, and Terrestrial Relations*. Published by the author, Chicago, 1915.

The pyroxene portion was again treated with pure methylene iodide to remove any minerals of lighter gravity. Naturally chromite was concentrated in the pyroxene portion by such a procedure and was later removed by hand picking. No silicate was rejected because after it was found that several different minerals were present the authors wished to get an analysis which included all of these minerals in their true proportions.

Bytownite.—When the feldspar is examined on the freshly broken surface of the meteorite two different colors and lusters are noticeable. One is white and more vitreous, similar to the bytownite of terrestrial rocks, the other has a dull luster and is slightly gray in appearance. What these two types of bytownite may signify the authors are unable to say. In thin section this difference is not noticeable and the analysis, as well as the determination of the optical properties were made upon a sample prepared as described above and containing both types of feldspars.

The bytownite contains numerous minute inclusions, most of which are without any symmetrical arrangement. Under the oil immersion objective the most common inclusion observed has a rather elongated rhombohedron shape and a brownish red color. There are a few inclusions of spherical habit, with a similar color, and some inclusions of slender, prism-like forms, rather uniform in shape, and arranged in rows along the direction of the cleavage.

The indices of refraction, determined by the immersion method using crushed fragments were found to be: $\alpha=1.571$; $\beta=1.578$; $\gamma=1.583$; $B=.012$. Sign (—), extinction angle on (010) is 36° , on (001) is 32° . Dispersion moderately strong, $r < v$. $2V=77^\circ$ (calculated).

BYTOWNITE, MOORE COUNTY METEORITE

E. P. Henderson, *analyst*

		Ratios		
SiO ₂	46.70	.7770	.7770	2+
Al ₂ O ₃	33.20	.3256	.3356	1
Fe ₂ O ₃	1.59	.0100		
CaO	17.42	.3106		
MgO	0.27	.0067	.3301	1
Na ₂ O	1.16	.0187		
K ₂ O	0.08	.0008		
TiO ₂	0.06			
	100.48			

The norms of this bytownite are: *an.* 86.38%; *ab.* 9.78%; *or.* 0.43%; with an excess of 1.92% of silica.

PYROXENE PORTION

A sample of this pyroxene aggregate was prepared by the same procedure as described under the preparation of the feldspar portion. The hand picked portion contained some unavoidable inclusions of chromite and perhaps some other opaque mineral. The specific gravity was found to be 3.67.

This portion, on first inspection, was thought to be a single homogeneous mineral, as the color was very uniform (brownish yellow), but on a careful optical study made by Miss Jewell J. Glass, it was found to consist of three components which could be distinguished from one another by their distinct optical properties. One of these minerals was hypersthene and the other two were pigeonites. It is unusual to find two modifications of a mineral whose compositions can be expressed as a mixture of different molecules of a solid solution series, in the same rock. Evidence is offered later in this paper to explain this apparent anomaly.

PYROXENES, MOORE COUNTY METEORITE

E. P. Henderson, *analyst*

		Ratios	
SiO ₂	49.37	.8220	.8220
Al ₂ O ₃	1.55	.0152	
Fe ₂ O ₃	1.83	.0115	
FeO	26.44	.3680	.8406
CaO	4.60	.0820	
MgO	15.54	.3854	
MnO	0.37	.0052	
TiO ₂	0.62	.0077	
	100.32		

Hypersthene.—The hypersthene has a brownish yellow to smoky yellow color, the grains are prismatic and have a good cleavage. Some show very fine twinning. The indices of refraction are: $\alpha=1.705$; $\beta=1.717$; $\gamma=1.720$; $B=.015$. Sign (—). $2V$ slightly variable, about 60° . Extinction parallel, dispersion weak, $r > v$. The optical plane is parallel to the elongation and also to the trace of the best cleavage. The grains are slightly pleochroic. X=pale pinkish brown, Y and Z=colorless.

Inclusions of both a transparent and opaque nature are numerous. There are some transparent inclusions arranged in a series of parallel interrupted rows, which might be mistaken for twinning lamellae. This apparent twinning structure in transmitted light gives a ridge and trough-like effect due to the difference in the index of refraction between the included bands and the host mineral. Other transparent inclusions show a flag- or figure "7"-like pattern arranged symmetrically either

parallel to the cleavage, or in rows inclined 25 to 30 degrees to the cleavage. The opaque included mineral has a rhomb-like form and no symmetrical arrangement in the hypersthene. Some of these opaque inclusions certainly are chromite and since there is some ferric iron present in the composite analysis, there may be some hematite present. Brookite of reddish color and of modified rhombic form, as well as titaniferous iron in rhombic forms have been reported in hypersthene.³

Pigeonite.—There are present two distinct compounds which can be recognized and distinguished from one another, both having optical properties which fall within the range included in the pigeonite series.

Pigeonite "A."—This modification of pigeonite is a far more abundant and important constituent than that described under pigeonite "B." The grains are prismatic with a vitreous luster, having two perfect cleavages and a good parting in a direction transverse to the best cleavage. Contact twinning is common and frequently an indistinct polysynthetic twinning occurs. The following table contains three separate sets of indices of this pigeonite which are listed for comparative purposes.

TABLE 1

Refractive Indices of Pigeonite "A" in Moore County, North Carolina, meteorite, determined by Jewell J. Glass.

α	1.706	1.705	1.705
β	1.708	1.707	1.708
γ	1.730	1.732	1.730

Sign (+). $2V=0^{\circ}-15^{\circ}$. Pleochroism distinct. X=pinkish brown, Y=pale pinkish brown, Z=faintly greenish (nearly colorless). Extinction $Z \wedge c=31^{\circ}$. Dispersion is strong, $r > v$. The dispersion phenomenon in this mineral is distinctive. The grey blue bands cover the entire area of the two opposite quadrants, and when the gypsum plate is interposed the other two quadrants are a deep rose reddish orange.

The direction of the optical plane is not easily determined; pieces which show centered figures are invariably irregular in outline and show no directional features. Optical figures are easily obtained, however, and the fragments which give a perfectly centered figure are distinctive, having a blue grey color in one position and a rose brown at 90° to this.

The inclusions in the pigeonite are limited to opaque ones of rhombic habit and in general are haphazardly arranged. There is a suggestion of definite arrangement of the tiny rectangular inclusions parallel and at right angles to a cleavage. The pattern found resembles those which have been noted in "Schiller structures."

³ Kosmann, *Jarb. Min.*, p. 532, 1869; p. 501, 1871.

The uniaxial augite, pigeonite, from the Island of Mull⁴ has the following indices: $\omega = 1.714$; $\epsilon = 1.744$; $B = .030$. According to Bowen and Schairer⁵ "in optical properties it shows a close approach to a pyroxene of the pure Mg-Fe clino series having MgSiO_3 (40%), FeSiO_3 (60%)." Since the optical properties of this modification of meteoric pigeonite agree with those of the pigeonite from the Island of Mull, it is evident that the composition is close to that given by the above authors for the latter locality. Comparing the optics of the pigeonite, here described, with Tomita's⁶ diagram, the same relative composition was obtained.

TABLE 2

	Clino-hypersthene	Pigeonite "B"
	Bluff, New Zealand	Moore County, N.C., meteorite
Observer	Harold Service	Jewell J. Glass
Twinning	Fine lamellar twinning on (100) frequent	Polysynthetic twinning, also contact twinning
Birefringence	.023	.029
Indices of Refraction	Mean index 1.72	$\alpha = 1.693$; $\beta = 1.696$; $\gamma = 1.722$
Sign	—	+
Optic plane	Parallel to traces upon (001) of (100) twins	Normal to cleavage
Pleochroism	$X = Y$ = pale rose pink; Z = pale apple green	X = pinkish brown; Y and Z = pale tan to brownish
Miscellaneous	$2V = 30^\circ \pm 3$	$2V = 30^\circ - 40^\circ$ $Z \wedge c = 38^\circ$ Dispersion moderate

Bowen and Schairer⁷ further comment on the Island of Mull pigeonite by saying: "There can be little doubt that the stable condition of the substance of this uniaxial augite at low temperatures would be an orthorhombic pyroxene with a small admixture of lime rich monoclinic pyroxene and the suggestion is that these crystals formed at a high temperature."

⁴ Hallimond, A. F., *Mineral. Mag.*, vol. 17, p. 97, 1914.

⁵ Bowen, N. L., and Schairer, J. F., *Am. Jour. Sci.*, vol. 29, p. 202, 1935.

⁶ Tomita, T., *Jour. Shanghai Sci. Inst.*, sec. V. 1, p. 41, 1934.

⁷ *Idem.*

Pigeonite "B."—It is estimated that this modification of pigeonite makes up slightly less than 5% of the total pyroxenes of this meteorite. It has a yellowish brown to smoky greenish color, vitreous luster and the grains of this variety are rounded. The fracture is irregular and cleavages are not as common as in the hypersthene. Twinning surfaces are observed, but less commonly than in the other pyroxenes present.

In the following table a comparison is made between the optical properties of clino-hypersthene from Bluff, New Zealand,⁸ and this modification of pigeonite in the Moore County, North Carolina, meteorite.

Interpolating the indices of refraction for this meteoric pigeonite in Tomita's diagrams⁹ the composition was found to be about 35% FeSiO_3 and 65% MgSiO_3 .

There is little variation in the observed indices of refraction for the subordinate pigeonite and the following table permits a comparison of the range of variations.

TABLE 3

Indices of Refraction of Pigeonite "B" in Moore County, North Carolina, meteorite. Determined by Jewell J. Glass.

α	1.693	1.692	1.692	1.692
β	1.696	1.694	1.695	1.696
γ	1.722	1.720	1.722	1.720

These two tables, Pigeonite "A" and Pigeonite "B", showing the variations in refractive indices of the two pigeonites are given not only to show the limits of variation but also to show that the results obtained are easily duplicated. Such careful work was thought to be necessary because it has been rare to find two such distinct modifications of pigeonite in terrestrial rocks. This feature leads to important deductions concerning the natural history of this meteorite.

In the andesite from Hakone volcano, Japan, Kuno¹⁰ describes a pigeonite occurring as phenocrysts, the core of each crystal is homogeneous but with a narrow marginal zone, with a larger optical angle and a slightly larger extinction angle than the central core. Kuno states "The narrow rim around each augite phenocryst (pigeonite) is richer in MgSiO_3 than, and nearly equal in CaSiO_3 content, to the core . . . judging from its lower refraction. From these facts and other marginal zones surrounding the hypersthene, plagioclase and augite, it may be interpreted that the phenocrysts in the rock are in reality xenocrysts that were enclosed just before extrusion by a magma more basic in composi-

⁸ Service, Harold, *Royal Soc. New Zealand*, vol. 64, p. 147, 1934.

⁹ *Idem*.

¹⁰ Kuno, Hisashi, *Jour. Geol., Soc. of Japan*, vol. 42, no. 496, p. 39, 1935.

tion than that with which they had been in equilibrium in the deeper portion, and that the narrow marginal zones around the phenocrysts, which were characterized in the above, are products of their reaction with this basic magma." The authors do not believe that Kuno's explanation of the two pigeonites in the Hakone lavas applies to the pigeonites in the Moore County meteorite.

RELATIONSHIP OF THE PYROXENIC MINERALS

It is evident from a study of the stony meteorites that they have not been through many recrystallizations or magmatic alterations and that the minerals in meteorites have not reached chemical equilibrium, so perhaps one might expect to find these two forms of pigeonite occurring together. We favor, however, the possibility that the complex assemblage of pyroxenic minerals found in this meteorite may be the result of a transformation resulting from a second reheating. There is abundant evidence from laboratory studies that transformations such as are recorded in this meteorite can easily take place.

It is now well established that both enstatite and hypersthene can be transformed from an orthorhombic to a monoclinic form. Allen, Wright and Clement¹¹ found that when the enstatite from the Bishopville meteorite was heated to 1450° the enstatite with its parallel extinction disappeared completely and was replaced by the twinned monoclinic lamellae. The latter still preserved the original prismatic direction of the enstatite and also apparently the cleavage, the size of the grain of the two phases being about the same and the original outline of the enstatite fragments being still preserved after the paramorphic change.

These same investigators¹² were able to reproduce parallel growths of enstatite and monoclinic pyroxenes by cooling rapidly a molten mass of pure magnesium silicate. They state: "The slower the cooling the more the monoclinic form is obtained; hence, we (Allen, Wright and Clement) conclude that the Bishopville meteorite was probably cooled rather rapidly from a high initial temperature."

Bowen and Schairer¹³ have described in detail the changes from orthorhombic to monoclinic forms in the MgO-FeO-SiO_2 system and many references will be quoted from their publication.

It has been proposed that quick cooling such as occurs in meteorites and artificial melts gives coarse twinning which is visible under the microscope, whereas slow cooling gives submicroscopic twinning. Bowen¹⁴

¹¹ *Am. Jour. Sci.*, vol. 22, p. 403, 1906.

¹² *Idem.*

¹³ *Am. Jour. Sci.*, vol. 29, p. 164, 1935.

¹⁴ *Am. Jour. Sci.*, vol. 38, p. 255, 1914.

found that "quick and slow cooling have precisely the opposite effects for pyroxenes." "When crystals form instantaneously from undercooled liquid the twinning is very fine; when they are grown by holding for a couple of hours in contact with liquid the twinning bands are broad."

If the different pyroxene minerals present in this (Moore County) meteorite represent a transition of one form to another by reheating, which seems to be the best explanation of their presence, it is more likely the reheating was done at the place of origin rather than in the course of its flight.

From the results of researches of Bowen and Schairer¹⁵ on the system MgO-FeO-SiO_2 , it appears that the original composition of this meteorite was bytownite and a homogeneous pyroxene mineral. The latter on cooling probably unmixed to give the orthorhombic pyroxene, hypersthene and pigeonite. The rock mass was at some later date reheated and a portion of the hypersthene was then transformed into the second modification of pigeonite present in subordinate amounts.

The following discussion is introduced to give some quantitative data concerning the temperatures necessary to effect these changes, and also to prove that such temperatures are more likely to be brought about by geological agencies in the meteorite's original environment than by friction with the atmosphere during its flight.

These same authors¹⁶ found that at somewhat higher temperatures than needed for the formation of orthorhombic pyroxenes, the monoclinic pyroxenes exist in equilibrium and correspond to the clino-enstatite, clino-hypersthene series. The inversion temperature of the MgSiO_3 end member is 1140° and the temperature of inversion falls off rapidly as the iron ratio is increased until the inversion of the iron rich member is approximately at 955° .

In their investigations, Bowen and Schairer used natural pyroxenes and also synthetic materials. They state: "We have found it impossible to induce any synthetic metasilicate mixture of the system to crystallize completely in the orthorhombic form." These authors used the enstatite from the Bishopville meteorite and found that when it was heated at 1150° for four hours partial transformation is readily discerned, recognizable under the microscope as twinned lamellae of the monoclinic form on the edges and corners of the grains, "at times small grains are transformed through and through to the twinned form." The twinning was found to be coarse and the extinction angle against the twinning is 22° .

It was also found that when enstatite was heated for 125 hours at

¹⁵ *Am. Jour. Sci.*, vol. 29, p. 151, 1935.

¹⁶ *Loc. cit.*

1140° not a trace of the monoclinic form was found. These authors suggest that all indications are that enstatite is stable up to about 1145° and will persist indefinitely at any temperatures below that. It will change at a measurable rate at a temperature even a few degrees above 1145°. It was also found that the inversion point for hypersthene from Mt. Dore¹⁷ was about 1090°.

Since the indices of the Mt. Dore hypersthene agree very closely with those given above for the hypersthene in this meteorite, it is logical to assume that the inversion point for the meteoric hypersthene would be similar to the hypersthene from Mt. Dore. Thus, when the meteorite was reheated, a temperature of 1090° must have been reached.

The following quotations from Bowen and Schairer give temperature ranges for the separation of the orthorhombic Mg-Fe pyroxenes.

"When Mg-Fe metasilicates crystallize from magmas it almost invariably assumes the orthorhombic form, stable at temperatures below 1140° at the magnesian end and below 955° at the other extreme. It is safe to conclude that crystallization of orthorhombic pyroxene took place below the temperature mentioned and since orthorhombic pyroxene is one of the earliest of minerals in these rocks in which it occurs the indications of low temperature crystallization of these rocks are clear."

"It is *not* safe to assume that the monoclinic Mg-Fe pyroxene must form only at high temperatures. It is a common observation that crystalline phases stable only at high temperatures may form metastably at low temperatures especially if rapidly formed."

It is not likely that this meteorite was heated high enough in its flight through the atmosphere to cause the inversion of the orthorhombic form into the monoclinic modifications. C. C. Wylie¹⁸ after some theoretical considerations concerning the size and limiting velocity of a falling body says: "At these low velocities the resistance of the atmosphere would generate such a small amount of heat that it would be rapidly radiated and conducted away. If a body of 500 pounds reached the earth with a speed of 400 feet per second the rate at which the atmospheric resistance would be doing work would be less than sufficient to raise its temperature one degree per second if it had a specific heat of unity. These calculations agree with the observed fact that no meteorites have been seen to fall as balls of fire and where definite observations are available they indicate that the ball of fire appearance ended at a height of several miles."

It is a well known fact that the heat caused by the friction with the atmosphere only penetrates a very short distance into iron meteorites.

¹⁷ Des Cloizeaux, *Min.*, II, vol. 18, 1874.

¹⁸ *Popular Astronomy*, vol. 42, p. 59, 1934.

Thus it was shown by Merrill¹⁹ that if the etched slice of the Toluca meteorite was heated for a few hours below red heat the original octahedral pattern assumed a granular structure. On continued heating the octahedral structure will disappear entirely.

That this meteorite under discussion may have passed close to our sun and at that time received enough heat to cause the pyroxene inversions is very unlikely. To be close enough to receive such heat would probably be so near that it would be drawn into our sun. Wherever and in whatever manner this meteorite was reheated the temperature must have been lower than the fusion point of bytownite.

Merrill²⁰ shows that feldspar can refuse and recrystallize without the formation of maskelynite. This observation is supported by researches on the melting points of feldspars.²¹ There is no detectable quantity of isotropic feldspar in this meteorite. There are a few spherical inclusions in the bytownite whose mineralogical nature is not understood, but it is difficult to see how these could be maskelynite.

Its presence is questioned because the very high temperature needed to melt this bytownite cannot be shown to have been reached in this meteorite. The norms of this bytownite are 9.78% albite, 0.4% orthoclase and 86.38% anorthite. Such a feldspar would melt at a temperature far above that needed to produce the inversion of orthorhombic pyroxenes into monoclinic forms. The melting point of this bytownite²² would be about $1510^{\circ} \pm 10$.

CONCLUSIONS ON THE RELATIONSHIP OF THE PYROXENIC MINERALS

From the properties described and the researches quoted above it appears that the original composition of this meteorite was bytownite and a single homogeneous pyroxene mineral which on cooling probably unmixed to give hypersthene and pigeonite. At some later date the mass was reheated and a portion of the hypersthene was transformed into a second and subordinate modification of pigeonite. The temperature attained in the second reheating was somewhere between 1090° , the temperature necessary to transform such a MgO-FeO hypersthene into the monoclinic form, and 1510° the fusion point of bytownite of the same composition as in this meteorite. The temperature was probably never much above that needed for the transformation.

The Glass.—The material taken for this study was carefully picked from the rear face of the meteorite where the thickest accumulation

¹⁹ U. S. National Museum, Bull. 149, plate 26.

²⁰ U. S. National Museum, Bull. 149, plate 2, figure 2.

²¹ Bowen, N. L., *Am. Jour. Sci.*, vol. 35, p. 577, 1913.

²² *Idem.*, p. 591.

was found. The glass is vesicular and contains small quantities of partly absorbed or incompletely fused minerals. The sample was crushed and all pieces containing any appreciable quantities of mineral inclusions were rejected, however, it was impossible to prepare a sample which was perfectly free from these inclusions.

In transmitted light the color of the glass is dark brownish olive green, its index of refraction is 1.632.

Although little information of any mineralogical character was expected to result from such an incomplete study of the glass it did seem worth while to make some chemical tests upon it. Since the sample was quite bulky, because of the gas cavities, it would have required the sacrifice of most of the glass attached to the meteorite to have prepared a pure sample in sufficient quantities to make a complete analysis. The prepared sample of glass weighed less than .5 gram and with such a small quantity it seemed advisable to spend it in determining the ferrous and ferric iron contents and the alkalis.

ANALYSIS OF GLASS, MOORE COUNTY, METEORITE

E. P. Henderson, *analyst*

FeO	8.96
Fe ₂ O ₃	7.53
Na ₂ O	0.68
K ₂ O	0.15

In the following table are arranged the analyses of bytownite, of the pyroxene portion, the average of these two analyses and the analysis of the complete stone. This table shows a striking agreement between the analysis of the complete meteorite and the average composition, and proves that the bytownite and pyroxene are present in equal proportions. Since the description of the separate component minerals is quite complete, there is nothing to add about the nature of the entire meteorite which would not be a duplication of what has gone before.

This meteorite is called eucrite, but this classification is not absolutely correct according to the classification of Rose-Tschermak-Brezina. Eucrites by their definition consist of augite with anorthite, while in the Moore County meteorite the pyroxene and bytownite constituents are present in equal quantities. However, it seems that the augites in their definition of eucrite can be taken to mean pyroxene minerals, including pigeonite of compositions similar to augites. Also the bytownite is very close to anorthite in composition.

It has been suggested that the granular structures of certain iron meteorites are due to reheating, but prior to this description there has been no evidence so convincing that stony meteorites also have been re-

heated. The Moore County meteorite offers very definite evidence of reheating.

TABLE 4
SUMMARY OF ANALYSES, MOORE COUNTY, METEORITE
E. P. Henderson, *analyst*

	Bytownite	Pyroxene	Average of two mineral portions	Complete meteorite
SiO ₂	46.70	49.36	48.03	48.16
Al ₂ O ₃	33.20	1.55	17.32	15.57
Fe ₂ O ₃	1.59	1.83	1.71	1.90
Cr ₂ O ₃	—	—	—	0.44
FeO	—	26.44	13.22	13.98
MnO	—	0.37	—	0.31
CaO	17.42	4.60	11.01	11.08
MgO	0.27	15.54	7.90	8.41
Na ₂ O	1.16	—	—	0.45
K ₂ O	0.08	—	—	0.09
TiO ₂	—	0.62	—	0.32
S	—	—	—	0.30
	100.48	100.32		100.54

The Moore County meteorite is now about equally divided between the U. S. National Museum at Washington, D. C., and the North Carolina State Museum at Raleigh, North Carolina. This meteorite fell near the town of Carthage, North Carolina, and would have taken that name had there not been one already described and named as the Carthage from Smith County, Tennessee. Thus to avoid confusion the geographic name of the county in which it fell in North Carolina was selected.

SUMMARY

A 4 pound, 2 ounce stony meteorite, eucrite, is described which fell at about 5 P.M., April 21, 1913, near Carthage, North Carolina.

The unusual coarse texture permitted a mineralogical study, which revealed the presence of three distinct pyroxene components—hypersthene and two pigeonites. The presence of the three members of this group can best be explained by assuming the meteorite had been reheated prior to its entrance into the earth's atmosphere. A temperature above 1090°C. is necessary to produce the mineralogical relationships found in this meteorite.

Chemical analyses are given of the bytownite, composite pyroxene components, and for the entire meteorite. Optical properties are given for bytownite, hypersthene, two pigeonites and the glass.

FULLER'S EARTH OF BENTONITIC ORIGIN FROM TEHACHAPI, CALIFORNIA

PAUL F. KERR AND EUGENE N. CAMERON,
Columbia University, New York City.

INTRODUCTION

Five miles east of Tehachapi Pass, between Bakersfield and Mojave, in Kern County, California, there occurs a deposit of Fuller's earth which has been developed by the Filtrol Company of Los Angeles for use in oil refining. The clay is mined by means of small tunnels and hauled on trucks to a siding on the Southern Pacific railroad, where it is stored for shipment to Los Angeles. A large bin has been built at the siding to provide storage for carload lots. Open construction of the bin permits air drying of the clay which at the same time results in a considerable amount of checking and cracking.

The locality was visited by the senior author during August, 1930, when samples were collected for laboratory study. Since that time other material has kindly been supplied by Mr. W. S. Baylis, formerly Vice-President of the Filtrol Company.

This material has been used for reference purposes in the study of other clay minerals, but only brief mention of the deposit has heretofore been made in the literature. Samples of the clay were furnished Dr. R. E. Grim as an example of Fuller's earth, and he included a brief petrographic description of the clay in his examination of the petrographic characteristics of Illinois Fuller's earths.¹ In addition, the activity and thermal dehydration curve of the clay have been studied by P. G. Nutting.² However, in view of the economic value of the clay, the lack of information as to its field occurrence, and the uncertainty expressed by Grim as to its origin, a more detailed discussion of the deposit appears warranted.

OCCURRENCE AND LITHOLOGY

The clay occurs as a bed about 8 feet thick contained in a flat-lying, predominantly volcanic, conformable series of strata forming a ridge in the Tehachapi Mountains. Overlying the clay and associated thin-bedded tuffs are several hundred feet of porphyritic volcanics, opalized in places and containing numerous amygdaloidal cavities. The clay bed has been traced by means of surface openings over a distance of about a mile. The section exposed at the mouth of a prospect tunnel is shown in Fig. 1. Figure 2 is a photograph of the same tunnel mouth.

¹ Grim, R. E., Petrography of the Fuller's earth deposits, etc.: *Econ. Geol.*, vol. 28, No. 4, p. 356, June, 1933.

² Nutting, P. G., The bleaching clays: *U. S. Geol. Survey, Circular 3*, 1931.

Below the clay are thin tuffaceous strata which are somewhat calcareous and contain a few fragmented plant remains. The origin of these strata is not as definitely determinable as in the case of the adjacent beds, but optical studies of thin-sections and crushed fragments from specimens representing these strata have shown the presence of montmorillonite and of scattered shard-like isotropic patches. Thus it appears that pyroclastic material has contributed to the formation of the beds. The white clay being mined appears to grade into this underlying bed.

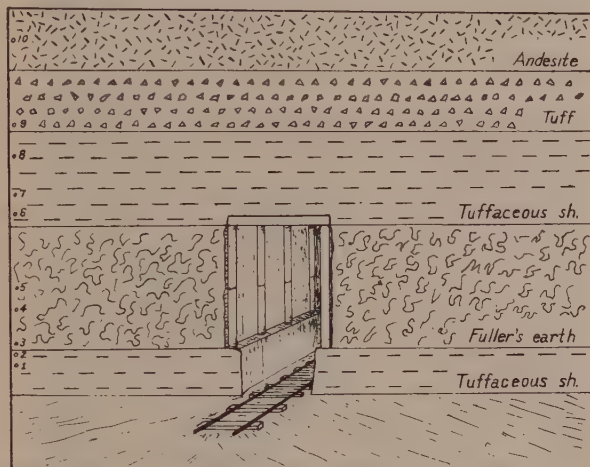


FIG. 1. A diagram illustrating the strata related to the Fuller's earth bed. Numbers at the left indicate the positions from which samples were taken for thin-section studies.

Above the white clay, with rather sharp contact, lie several feet of fine-textured, somewhat calcareous shaly strata similar in composition to the beds below, but more evidently pyroclastic in origin. Montmorillonite figures prominently in the matrix of the shaly strata, and shard-like forms are abundant. A few angular fragments of feldspar are also scattered through the matrix. Overlying these shaly beds are several feet of andesitic tuff (Fig. 3) containing abundant angular fragments of crystals, chiefly andesine, hornblende, and biotite, in a matrix of glass partly altered to montmorillonite. Lithic fragments of tuffs and of several types of felsites are also present. Occasional patches of opal replacing the groundmass may be observed. The exposure is capped by a porphyritic hornblende andesite flow (Fig. 4) several hundred feet thick, containing abundant phenocrysts of zoned feldspar (of average intermediate composition), hornblende, biotite, titanite, and magnetite in a hyalopilitic groundmass consisting of felted oligoclase-andesine microlites with some interstitial glass.

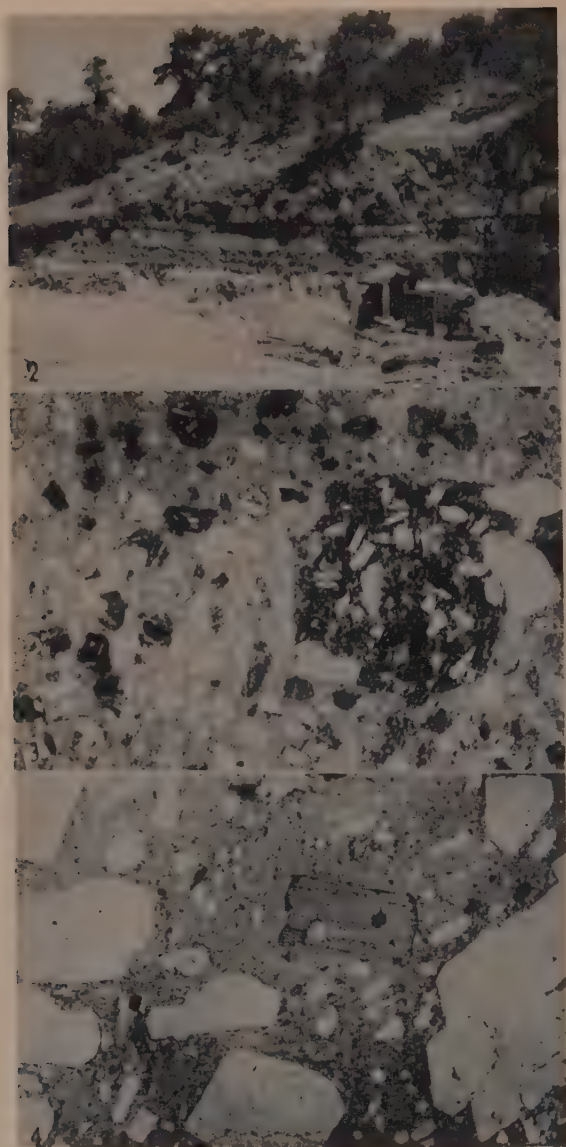


FIG. 2. Photograph showing an outcrop of the Fuller's earth. The white bed at the bottom of the cut at the same level as the tunnel entrance is Fuller's earth.

FIG. 3. Photomicrograph $\times 20$. Angular crystals distributed through tuff together with one large lithic fragment and several small ones.

FIG. 4. Photomicrograph $\times 20$. Coarse feldspar phenocrysts in a fine matrix, illustrating the andesite overlying the Fuller's earth deposit and associated tuffs.

The strata are flat-lying and seem to be little disturbed, aside from a few faults of minor displacement which appear to have no bearing on the present discussion. The age of the beds was not established but, judging from the history of the region, is probably late Tertiary. Fossil evidence was lacking in the samples studied.

Specimens for microscopic study were taken from each of the beds from the points indicated by numerals in Fig. 1, and in addition from various points along the outcrop of the clay bed. Microscopic studies have been supplemented with x-ray diffraction patterns and chemical analysis.

CHARACTERISTICS OF THE TEHACHAPI CLAY

The clay is typically white or light grayish-white, but some specimens show a greenish tint, particularly when moist. It is coarsely bedded and fractures irregularly into massive, structureless blocks. Freshly broken surfaces have a rough, gritty "feel," as a rule, although one of the specimens collected shows smooth surfaces with an approach to a conchoidal fracture, apparently due to extreme fineness of texture. The Tehachapi clay shows no tendency to swell when placed in water. Near the base of the bed the clay contains poorly preserved plant remains.

Grim³ found it impossible to determine the origin of the clay from the material which he studied, although he found traces of what might be relicts of a vitroclastic structure. Most of the specimens examined in the course of this study present the same difficulty; but two, in which the original ash apparently had a coarser texture than is normal for the bed, show a well preserved relict "bogen" structure in thin-section. Figure 5 is a photomicrograph of a part of a thin-section of the coarser of the two specimens. The structure alone is sufficiently clear to leave no doubt that the clay has been derived by alteration of a volcanic ash. This conclusion is supported by the discovery of shards which have not yet been completely altered to montmorillonite. Indeed, all stages in the alteration of the shards have been observed in the section illustrated in the photomicrograph, from shards only slightly altered to those completely converted to montmorillonite and recognizable only by the "ghost" outlines of the originals. Occasionally a single shard is found to be composed partly of glass and partly of montmorillonite. Except in these two specimens alteration has been complete enough to destroy all but traces of the original ash structure, the result being an extremely fine aggregate of montmorillonite.

The chief component of the clay is montmorillonite of micaceous habit, occurring in wavy or twisted flakes which show a rude orientation

³ Grim, R. E., *op. cit.*

parallel to the bedding of the clay. In the air-dried clay the montmorillonite has the following optical properties: $\gamma = 1.506$; $\gamma - \alpha =$ approximately .020; (—) 2V moderate; elongation positive; extinction nearly parallel to the long direction of the flakes. Both index of refraction and birefringence decrease with increase in the moisture content of the clay.

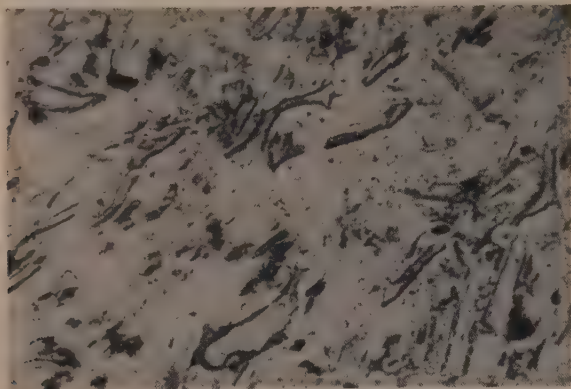


FIG. 5. Photomicrograph $\times 95$. Shard structures preserved in Fuller's earth at the Tehachapi deposit.

In addition to montmorillonite, specimens of the material studied by the writers contain varying amounts of a clear, colorless, platy mineral. It is isotropic to weakly birefringent and has an index of refraction (about 1.475) which is too low for volcanic glass. Insofar as its properties could be determined, they correspond to those of clinoptilolite⁴ as described by Bramlette and Posnjak.⁵ Attempts to concentrate this substance by mechanical means sufficiently for x -ray determination were unsuccessful. A mixed x -ray diffraction pattern contains lines which agree with the pattern for heulandite as far as the two could be compared. The mineral is of interest because it appears to represent an intermediate stage in the alteration of volcanic glass to montmorillonite. It occurs as a constituent of the clear portions of certain of the less altered shards, some of which consist in part of this substance, in part of montmorillonite. The fine aggregate structure of the clay makes it difficult to estimate the percentage of this substance present, but it probably does not exceed 10%.

In addition to the components named above, the residue of the clay after crushing and washing contains angular fragments of sanidine,

⁴ According to Hey, M. H., and Bannister, F. A., (*Mineral. Mag.*, vol. 23, No. 145, pp. 556–559, 1934) clinoptilolite is a silica-rich heulandite.

⁵ Bramlette, M. N., and Posnjak, E., Zeolitic alteration of pyroclastics: *Am. Mineral.*, vol. 18, pp. 167–171, 1932.

oligoclase-andesine, hornblende, and chlorite. A little leucoxene and limonite have occasionally been observed. Grains of the minerals just mentioned attain a maximum size of .25 mm., but the average is much lower. In all they form less than 1% of the clay.

CHEMICAL ANALYSIS

The following is an analysis by Mr. A. M. Smoot, of Ledoux and Company, of an air-dried sample of Tehachapi clay:

H ₂ O at 110°C.....	8.21%
H ₂ O above 110°C.....	9.98
SiO ₂	53.88
Al ₂ O ₃	11.66
FeO+Fe ₂ O ₃	4.60
MnO.....	0.18
CaO.....	1.56
MgO.....	8.61
TiO ₂	0.44
K ₂ O.....	0.39
Na ₂ O.....	0.15
P ₂ O ₅	0.16
CO ₂ , SO ₃ , ZrO ₂	none
	<hr/> 99.82%

In view of the fact that the analysis includes the zeolitic constituent of the clay as well as montmorillonite, it agrees fairly well with the analyses of montmorillonite-bearing bentonite given by Ross and Shannon.⁶ The silica content is higher than the average, presumably due to the presence of the zeolitic substance described above. The water is correspondingly low. Iron oxide and MgO are higher than the average, while Al₂O₃ and CaO are lower.

The optical data furnished by the clay mineral indicate a member of the montmorillonite group low in iron.⁷ Also, the occasional patches of limonite present in thin sections of the clay seem insufficient to account for the excess of iron. Some of the iron oxide may be present as adsorbed iron, which may be responsible for the slightly brownish color of certain clay fragments under the microscope. However, the status of the iron in the clay is uncertain. The markedly high magnesium oxide presents a similar difficulty. Since no carbon dioxide was found by analysis of the clay, the magnesium oxide cannot be ascribed to finely divided magnesium carbonate. It may indicate a slight gradation toward saponite. The low percentages of calcium and aluminum oxides are interpreted as reflecting the high percentages of iron oxide and magnesia.

⁶ Ross, C. S., and Shannon, Earl V., The minerals of bentonite and related clays and their physical properties: *Jour. Am. Cer. Soc.*, vol. 9, No. 2, p. 79, 1926.

⁷ Ross, C. S., and Kerr, P. F., The clay minerals and their identity: *Jour. Sed. Petrology*, vol. 1, No. 1, p. 59, 1931.

X-RAY EXAMINATION OF TEHACHAPI BENTONITE

X-ray diffraction measurements of montmorillonite are already on record.⁸ The material from Tehachapi furnishes x -ray diffraction patterns which agree with the recorded measurements and also exhibit additional lines which match the lines given by patterns of heulandite from West Paterson, N. J.; Iceland; and Cape Blomidon, N. S. Hey and Bannister⁹ and Bramlette and Posnjak¹⁰ have made x -ray studies of heulandite and related zeolites. The clinoptilolite of Bramlette and Posnjak yields an x -ray diffraction pattern indistinguishable from that of heulandite. Hey and Bannister find that such material also yields rotation photographs of similar agreement. Whether or not clinoptilolite is actually silica-rich heulandite as Hey and Bannister conclude, the material of the Tehachapi clay appears to correspond to their description and also to the description of the clinoptilolite of Bramlette and Posnjak. Too little material could be separated to attempt to reconcile the different viewpoints.

CLASSIFICATION OF TEHACHAPI BENTONITE

In 1926 Ross and Shannon¹¹ proposed the following definition of bentonite:

Bentonite is a *rock* composed essentially of a crystalline clay-like mineral formed by devitrification and the accompanying chemical alteration of a glassy igneous material, usually a tuff or volcanic ash . . . the characteristic clay-like mineral has a micaceous habit and facile cleavage, high birefringence and a texture inherited from volcanic tuff or ash, and it is usually the mineral montmorillonite, but less often beidellite.

The clay from Tehachapi has been shown to satisfy each of the requirements of the above definition; hence from the petrographic standpoint it may be classified as a bentonite.

As stated at the beginning of this article the clay has been used as a Fuller's earth by the Filtrol Company of Los Angeles, California, in treating petroleum oil. Although a natural bleaching agent, it has been reported to be poorly responsive to the usual acid treatment applied to commercial adsorptive clays. In connection with his study of the bleaching clays, Nutting¹² tested the activity of Tehachapi clay. He makes the following comment on the tests:

The rating of active minerals according to their bleaching efficiency is obviously a quite arbitrary matter, because the relative bleaching power of any series of clays will be different for every test liquid used. . . . Even with a specific clay and test oil there is the question of which cut to choose as standard. . . .

⁸ Kerr, P. F., Bentonite from Ventura, Calif.: *Econ. Geol.*, vol. 26, No. 2, p. 166, 1931.

⁹ Hey, M. H., and Bannister, F. A., *op. cit.*

¹⁰ Bramlette, M. B., and Posnjak, E., *op. cit.*

¹¹ Ross, C. S., and Shannon, Earl V., *op. cit.*

¹² Nutting, P. G., *op. cit.*, p. 43.

The tests here reported refer to complete filtration (to water-white), and the numerals under "Bleaching rating" . . . are the ratios of volumes of oil so filtered to the volumes of clay so filtering it The test oil was a high-gravity black natural petroleum, free from sulphur. Obviously this rating has little practical significance and was chosen partly for that reason.

On the basis of the above standard, the rating obtained for Tehachapi clay was 1.2, a value unchanged by treatment with acid. The ratings obtained for other active clays by this test ranged from .2 to 1.8 before, and .3 to 2.0 after treatment with acid.

Though arbitrary, these tests indicate the natural bleaching activity of the clay, and in view of the foregoing statements it seems proper to classify the Tehachapi clay as a Fuller's earth of bentonitic origin. The occurrence of montmorillonite as an essential constituent of Fuller's earth has already been mentioned.¹³

ORIGIN OF TEHACHAPI BENTONITE

The relict bogen structure of the clay is the best evidence for its origin by alteration of a volcanic ash bed. The coarse plant remains at the base of the clay bed seem significant of moisture at least sufficient for normal plant growth at the time of deposition. The regularity of the bedding of the series of strata in which the clay occurs, which becomes a fine lamination in parts of the series, suggests deposition in shallow water perhaps in an old lake bed.

SUMMARY

A commercial deposit of clay having the natural decolorizing properties of Fuller's earth occurs near Tehachapi, Kern County, California. The clay is essentially a mixture of montmorillonite and a zeolite, probably heulandite. Although commercially a Fuller's earth, study of thin-sections demonstrates that the clay has been derived from volcanic ash by alteration, and according to the petrographic definition it has the origin of a bentonite. It seems worth while therefore to place on record a description of the occurrence of a Fuller's earth of bentonitic origin.

¹³ Kerr, Paul F., Montmorillonite or smectite as constituents of Fuller's earth and bentonite: *Am. Mineral.*, vol. 17, pp. 192-198, 1932.

BENTONITIC MAGNESIAN CLAY-MINERAL FROM CALIFORNIA

W. F. FOSHAG* AND A. O. WOODFORD,
U. S. National Museum and Pomona College.

OCCURRENCE

The clay-mineral which is here described was found on the Mojave Desert, in folded sediments of probably Tertiary age. The locality is the "Company No. 1" quarry, three miles south of Hector, in San Bernardino Co., California.

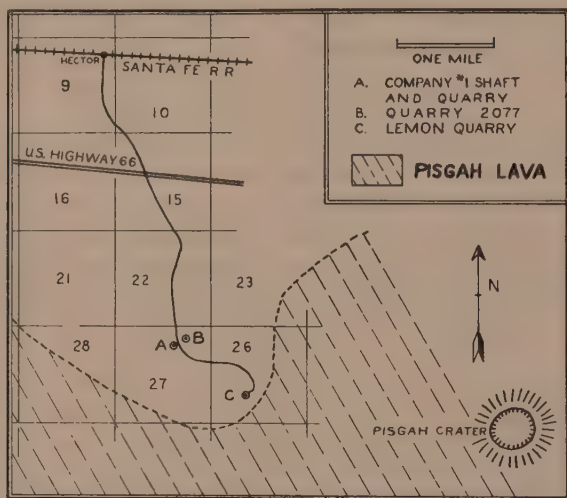


FIG. 1

Company No. 1 quarry is one of three more or less developed prospects on properties of the California Talc Company near Hector. All three prospects have yielded light-colored, swelling bentonitic clays. One lies three to three and one-half miles northwest of Hector station on the Santa Fe Railroad.

The other two prospects are south of Hector station and are less extensively developed. The Lemon quarry in section 26 (C in Fig. 1) discloses a one to three foot, irregular, distorted bed of brown to pale lemon colored clay. This bed is part of a sand-clay-tuff series. The swelling, pale yellow clay contains chalcedony and calcite concretions. Company analyses are said to indicate a magnesium-aluminum clay (normal bentonite).

* Published by permission of the Secretary of the Smithsonian Institution.

The third prospect is Company No. 1 quarry in section 27 (A in Fig. 1). The bentonitic magnesian clay-mineral here described came from this locality. This prospect is apparently on a small anticline in a Tertiary volcanic series, originally almost completely unconformably overlain by the edge of a flow of basaltic lava extending northwestward from Mt. Pisgah.¹ At a little quarry 200 yards northeast of Company No. 1 (B in Fig. 1, Quarry 2077) the dips of the exposed beds suggest another small anticline, and the Lemon outcrops may indicate a third.

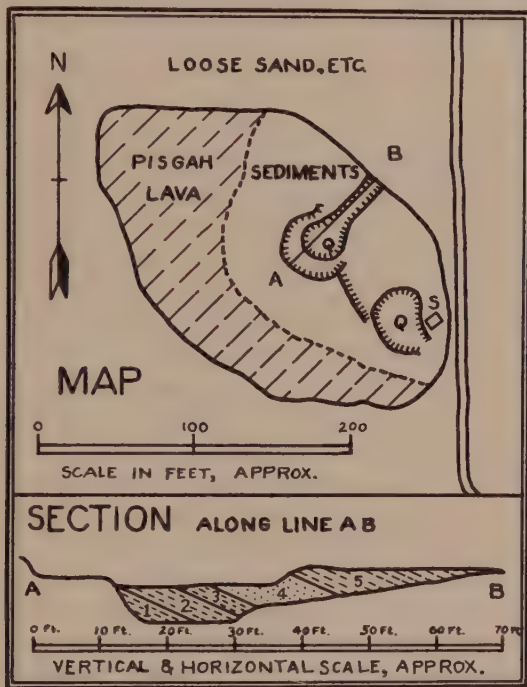


FIG. 2

As shown in Fig. 2, the brown sandy clay at Company No 1 is interbedded in a sand and clay series. The lower part of this series is tuffaceous, the upper part probably eolian. The bentonitic magnesian mineral is a white to cream-colored, swelling clay which appears to develop at the top and in cracks of the tuff (bed No. 2) and is obviously secondary. Hundreds, perhaps thousands, of pounds of it have been removed from the quarries. A sample furnished by the Flintkote Corporation was used for a chemical analysis and x-ray study. Other samples, collected by A. O.

¹ U. S. Geol. Surv., Bull. 613, pp. 158-159, 1916.

Woodford at the same spot, were used for both optical and chemical study.

A partially timbered shaft (S in Fig. 2) 35 feet deep in 1934, exposes in its lower half complexly cracked and slickensided buff clays and sandy clays (tuffs), which underlie those exposed in the quarries and which contain calcite and a little plastic clay in cracks and seams.

The small and shallow quarry 2077 (Fig. 1) exposes a few feet of clayey and sandy beds somewhat similar to those at Company No. 1. Some calcite nodules found in brown clay from Quarry 2077 are coated with white clay chemically and optically almost identical with that at Company No. 1.

PHYSICAL PROPERTIES OF THE MAGNESIAN CLAY

The swelling clay from Company No. 1 quarry is mottled white to pale brown in color, and has an earthy to semi-waxy luster. Scattered through this clay are pale buff calcite crystals two to three millimeters in length. The clay is translucent on the edges of the purer masses and transparent under the microscope. The dried material shows numerous shrinkage cracks and crumbles readily into lumps.

The white clay swells immediately when placed in water and soon becomes a gelatinous mass, which, after 24 hours, is a firm jelly estimated to be five or six times the volume of the original dry clay.

In thin-sections the swelling clay is distinctly crystalline. Between crossed nicols the material shows weak to medium birefringent areas with a speckled or reticulated pattern. The more strongly birefringent (coarser grained) portions are arranged in minute veinlets. The appearance of the clay in thin-section resembles many serpentines in structure. No relic structures were observed in thin-sections of this material.

Studied in oils under the microscope, the white clay is seen to be made up of tangled masses of minute doubly-refracting grains, and somewhat larger plates, with a poor basal cleavage. The indices of refraction are somewhat variable: $\gamma = 1.500 - 1.520 \pm .005$, and $\gamma - \alpha = .020 \pm .005$. Extinction is roughly parallel to the basal sections of the plates; elongation is usually positive but sometimes negative. No interference figures were obtained. Most plates are probably optically negative. The white clay from Quarry 2077 is optically similar, made up of grains and plates .003—.015 mm. in diameter, but with slightly lower indices. $\gamma = 1.490 \pm .005$. The white clays contain a few mineral grains identical with those of the brown tuff, described below.

CHEMICAL COMPOSITION OF THE MAGNESIAN CLAY

For analysis the pure white clay-mineral from Company No. 1 quarry, free from carbonate grains, was selected. Under the petrographic mi-

croscope the mineral appeared essentially pure and had a mean index of refraction of 1.500. The analysis, carried out by standard methods is given in Table 1, No. 1. From this analysis it is evident that this clay is essentially a magnesium silicate with only an insignificant amount of alumina present. Noteworthy is the high soda content (3.00%), and particularly the lithia content (1.12%).

TABLE 1. CHEMICAL COMPOSITION OF HECTOR CLAY

	1	2	3	4	5	6	7	8	9
SiO ₂	53.68%	.8736	51.26%	.8501	50.89%	.8437	43.00%	23.42%	14.72
Al ₂ O ₃	0.60	.0059	0.36	.0035	9.40	.0920	3.48	9.00	1.40
Fe ₂ O ₃			0.09	.0006	2.06	.0129	1.76		
CaO	0.52	.0093	2.60	.0463	0.78	.0139	9.06	0.00	22.32
MgO	25.34	.6285	23.25	.5766	26.52	.6577	17.11	15.26	21.75
FeO			0.06	.0012					
Sr			tr.	.0011					
Na ₂ O	3.00	.0484	3.47	.0560				0.20	
K ₂ O	0.07	.0007	0.10					1.25	
Li ₂ O	1.12	.0375	0.60	.0204				0.50	
H ₂ O+	8.24	.4574	5.14	.2853	11.06			4.96	8.34
H ₂ O—	7.28	.4041	11.56	.5902					
Cl	0.31	.0087							31.50
CO ₂			1.35	.0307					
F			None						
Insoluble							1.83		
Ignition									
loss							19.60		
Soluble									
salts							2.60		
Totals	100.16%		99.84%		100.71%				

1. Hector clay, California. W. F. Foshag, *analyst*.

2. Molecular ratios of No. 1.

3. Hector clay, California. R. E. Stevens, *analyst*.

4. Molecular ratios of No. 3.

5. Saponite, Svardsjö, Sweden. Svanberg, *analyst*, 1840.

6. Molecular ratios of No. 5.

7. Lucianite from near Mexico City. E. W. Hilgard, A peculiar clay from near the City of Mexico: *Proc. National Acad. Sci.*, vol. 2, pp. 8-12, 1916.

8. Tertiary clay, 16 miles northeast of Amboy, California. J. D. Laudermilk, *analyst*, 1935.

9. Marl, Borax Mine, Callville Wash, Nevada. W. F. Foshag, *analyst*.

A second analysis, (Table 1 No. 3), by R. E. Stevens of the U. S. Geological Survey on material collected by Bernard Moore has been made available to us by Dr. Clarence S. Ross.

Spectrographic examination of another sample from the same quarry, made by Dr. T. G. Kennard of the Claremont Colleges, showed, in addition to the elements listed in Table 1, considerable F, a small amount of Sr, and traces of Ba, B, Fe, Mn, Ti, V.

X-RAY EXAMINATION

The material used for our analysis was also used for an *x*-ray examination by the powder method. Samples of typical sepiolite from Cerro Mercado, Mexico (analyzed), saponite from Cook's Kitchen, Cornwall, and spadaite from Capo di Bove, Rome, similar magnesium silicates, were also photographed for comparison. The powder photographs of the clay showed distinct diffraction lines, indicating a crystalline nature. Comparison with *x*-ray spectra of sepiolite and spadaite showed marked differences. A comparison with saponite, however, showed a similar but not identical spacing of the diffraction lines, the lines of the Hector mineral being slightly displaced with respect to those of saponite. This indicates that the Hector mineral is closely related but not completely similar to true saponite. The relationship of the spectra of the two is indicative of isomorphism between the two compounds.

PHYSICAL AND CHEMICAL PROPERTIES OF THE BROWN TUFF

The brown tuff (bed No. 2 of Fig. 2) with which the magnesium clay is associated and from which it presumably is derived, is fairly hard, and has a somewhat waxy appearance on fresh fractures. It does not swell or disintegrate in water, though it may be broken by the swelling of minute white clay veins.

This tuff was studied in thin-sections and in oils. The sections show tangles of clay flakes, in which lie a few isolated grains of plagioclase, quartz, etc., 0.1 to 0.5 mm. long. The clay-mineral has a basal cleavage, with indices $\beta = \gamma = 1.520 \pm .005$ (determined in oils) and $\gamma - \alpha = .021 \pm .003$. Extinction $0^\circ - 15^\circ$ and perhaps higher; elongation usually positive. Exceptions may be only apparent, as cleavage seems to *cross* areas of negative elongation.

The greater part of the large grains are plagioclase, including both crystals and broken fragments. Indices and extinction angles indicate 28–30% An, or oligoclase-andesine. Some quartz grains are doubly terminated crystals, much corroded. Some quartz shows undulatory extinction. There are also present shiny euhedral plates of biotite, crystals and fragments of pyroxene, probably augite, abundant minute octahe-

drons, complex crystals and irregular bits of magnetite, and a few minute zircon crystals.

A partial bulk chemical analysis of the altered brown tuff (A. O. W. 2082D) and its included crystals, was made by J. D. Laudermilk of Pomona College, with the following results:

SiO ₂	52.20%
Al ₂ O ₃ and Fe ₂ O ₃	8.10
CaO	0.56
MgO	19.86
Loss on ignition	13.71

Spectrographic examination by Dr. T. G. Kennard of the Claremont Colleges showed, in addition, some Na and less Li, with a very little K, and traces of Sr, Ba, Cu, Ti, V, B and Mn. Fluorine indeterminate.

Relic textures are present in abundance in the clay matrix. They include minute collapsed cavities, lined with layers of the clay-mineral, and also curved structures which may be altered pumice shards. It seems probable that this rock is a greatly altered dacite tuff. The clay-mineral, of which the rock is now chiefly composed, is chemically and optically almost identical with the magnesian clay-mineral, but differs from it by not swelling greatly in water. In origin, therefore, this bentonitic magnesian clay is not essentially different from most normal bentonites.

EXTENT OF MAGNESIAN CLAYS IN THE MOJAVE DESERT

No general chemical study of the Tertiary bentonites and other clays of the Mojave Desert has been made by us. However, we have incidentally examined a clay for Mr. William Hunger of Los Angeles which came from a point 16 miles northeast of Amboy, and hence 65 miles east of Hector. This clay is hard, and high in calcite. A partial analysis of this clay is given in column 8, Table 1. After subtracting CaCO₃, this analysis is surprisingly close to that of the Hector clay, even to the minor constituents. The clay-mineral is too fine grained to yield definite optical data. It is probably birefringent.

Similarly in a marl associated with the borax deposits of Callville Wash, Clark County, Nevada, (analysis 9, Table 1) after deducting lime and magnesia, equivalent to the carbonate content, there is left a magnesia-silica residue with ratios very close to those of the Hector mineral. In the bentonitic clays of Ash Meadows, near Shoshone, California, there are numerous lumps of mixed lime, magnesia carbonates and a magnesian silicate close to sepiolite.

The magnesite beds near Bissell, contain silica and an excess of magnesia in ratios similar to those of the Hector clay. Borax-bearing marls from Cave Springs Wash, Nevada, show similar features.

FORMULA OF HECTOR CLAY AND RELATION TO OTHER MINERALS

The analysis of Hector clay given in Table 1 (No. 1) corresponds fairly closely to the formula $7\text{MgO} \cdot 10\text{SiO}_2 \cdot 5\text{H}_2\text{O}$, while that of No. 3 is close to $2\text{MgO} \cdot 3\text{SiO}_2 \cdot 3\text{H}_2\text{O}$, if one disregards the alkali content as adsorbed and not essential to the mineral molecule proper.

As can be seen from Table 1, Hector clay is chemically similar to the original saponite from Svardsjö, Sweden (No. 5). It may be close to the magnesian constituent of Hilgard's lucianite (No. 7), and it is probably significant that lucianite was described as a clay which swelled in water to 25 or more times its dry volume. Unfortunately no microscopical examination of lucianite, a surface clay from the Valley of Mexico was reported by Hilgard, and we can find neither Hilgard's locality nor his samples, despite searches at Mexico and the University of California.

ACKNOWLEDGMENTS

This clay was first studied for the Flintkote Corporation and we are grateful to Mr. L. Kirschbraun and the Flintkote Corporation for permission to publish the results. The base map for Fig. 1 was kindly furnished by the California Talc Company. For the x -ray diffraction photographs, we are indebted to Mr. Charles J. Ksanda, of the Geophysical Laboratory. We were assisted in the field by Mr. T. F. Harris.

SUMMARY

A bentonitic clay from deposits three miles south of Hector, San Bernardino County, California, is a hydrous magnesium silicate related to saponite. It is further unusual in its appreciable lithia content (about 1%). Similar magnesian clays are widespread in the Mojave Desert Region of California and Nevada.

IMMERSION LIQUIDS OF HIGH REFRACTIVE INDEX

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INTRODUCTION

For examination of materials under the polarizing microscope, and for other optical purposes, such as the measurement of refractivity of solids by the total reflection method, it is desirable to extend the range of immersion liquids as far as possible in both directions. The equation of state enters into the problem of finding liquids of extreme refractive index, whether high or low. Molecular refraction or polarizability runs parallel to the inter-molecular attractive forces. In consequence of this the high refractive index limit for the liquid state is set by the tendency of high index liquids to solidify under strong attractive forces—high internal pressure is the term sometimes used—just as they do under high external pressures. Conversely, the low index limit is set by the tendency of molecules, whose force fields are weak, to escape into the gas phase.

Attractive forces also vary with the strength of the molecular dipoles. The highest index liquids will be weakly polar if at all, for in this way the attractive forces are kept to the possible minimum. The lowest index liquids will be strongly polar, since such will be less volatile than non-polar liquids of the same refractive index. This advantage of polar substances in point of lower volatility is sometimes overlooked by mineralogists in making up sets of low index immersion liquids.

The prototype of high index liquids is yellow phosphorus—molecular weight 124, density 1.84, melting point 44° , refractive index 2.10. The tetratomic molecules of this element are dipole free, probably symmetrical tetrahedrons. The liquid, according to J. H. Hildebrand, is characterized thermodynamically by an extremely high internal pressure.

The prototype of low index liquids is hydrocyanic acid—molecular weight 27, density .702, boiling point 26° , refractive index 1.267. The molecules are linear and strongly polar. Other liquids of this class are water ($n=1.33$) and hydrofluoric acid (refractive index unknown). The condensed phase which will have the lowest refractive index is helium, whose intermolecular attractive forces are known to be the weakest of all substances; however, it can hardly be used as an immersion liquid under ordinary conditions.

By going to liquid systems of more than one component the rules of phase equilibria suggest possible gains at both ends of the liquid-refractive index scale.

SET OF HIGH INDEX LIQUIDS

The use of yellow phosphorus as a component of high index liquids has been suggested from time to time during the past seventy-five years.

Madan¹ pointed out the non-inflammable qualities of phosphorus-methylene iodide mixtures, and Borgström² described the use of phosphorus-sulfur mixtures with a third component, carbon disulfide or methylene iodide. The practical possibilities of such liquids have nevertheless received little attention from mineralogists.

We have found that a series of clear pale yellow liquids containing phosphorus-sulfur-methylene iodide, having the index range $n_D = 1.78 - 2.06$, is quite suitable for immersion purposes. The liquids are much less reactive than phosphorus alone, and with simple precautions may be used with confidence. They are reasonably constant in refractive index over a period of months when suitably stored. The sulfur depresses the solidification point below room temperature, the methylene iodide reduces the inflammability; although other substances could be used for the same purposes, the two named are preferred by reason of their high refractive index, low volatility and chemical stability.

Ternary System P-S-CH₂I₂. In making up high index liquids it would be desirable to have more information concerning solid-liquid phase equilibria in this ternary system, and in the corresponding one containing selenium. To date not even the binary systems have been examined in detail. Probably the P-CH₂I₂ and S-CH₂I₂ will be simple eutectics. The P-S system is remarkable not only for the ease with which the liquid phase may be supercooled, but also for the marked variation in properties with heat treatment. When these two components are mixed, without heating above 100° they are said to give a simple eutectic at 9.8° containing 22.8% S; but stronger heating brings about the formation of a series of solid sulfur-rich compounds with evolution of heat. The subject is reviewed by Mellor.³ It is expected that the ternary diagram for the unreacted system will have the appearance of Fig. 2.

The P-Se system has properties similar to those of P-S. It has recently been examined by Robinson and Scott.⁴ Borgström mentioned P-Se liquids with n_D up to 2.17, but these were dark and unstable in contrast to the P-S liquids.

Preparation. The 2.06 liquid is made by gently warming under water a mixture of yellow phosphorus (handle under water!), sulfur (can be obtained recrystallized from carbon disulfide), and methylene iodide in the approximate weight ratio of 8:1:1. Overheating is to be avoided. By mixing the 2.06 liquid with methylene iodide the graded series of liquids is made up, having compositions on the line drawn from point A in Fig. 2.

Optical Properties. The optical constants of the liquids were measured by minimum deviation through a hollow 50° prism.

A comparison of the present measurements with those of previous

writers⁵ is shown in Table 1 and Fig. 1. Dispersion $n_F - n_C$ increases from .038 to .065 as n increases from 1.74 to 2.06; the value .065 was also found by Damien for phosphorus. The temperature variation of n remains constant at .00065 per degree according to the accepted value for methylene iodide and the present value for the 1.99 liquid (range 6–27°).

TABLE 1. OPTICAL PROPERTIES OF HIGH INDEX LIQUIDS

	n	$n_F - n_C$	$-\Delta n / \Delta t$	Curve Fig. 1	Source
P (solid) 29°	2.15	.065	.00053	I	Damien, 1881
P (liquid) 44°	2.10	.063	.00116		
P-S-CH ₂ I ₂ 25°	2.06	.065	—	II	This work
	1.99	.058	.00065	III	
P-CH ₂ I ₂ satd. 18°	1.94	.055	—	IV	Madan, 1897
CH ₂ I ₂ 15°	1.74	.038	.00064	V	Timmermans, 1932

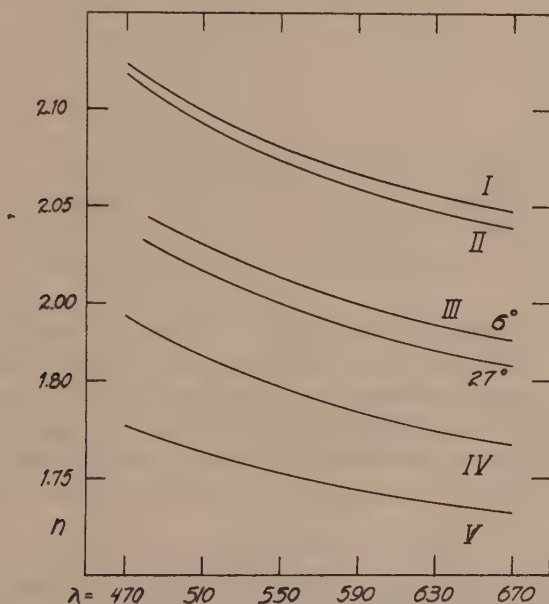


FIG. 1. Dispersion curves of high index liquids (see Table 1).

Damien reported a higher value for liquid phosphorus, namely .00116 per degree for the range 44–53°.

Storage, Stability. The phosphorus liquids are stored in glass stoppered bottles which are kept in a covered metal container; the latter to reduce fire hazard and to exclude light which has an adverse effect. In the present experiments a half inch layer of water was kept over the liquids, and

glycerine was also found to be satisfactory. Under these conditions the refractive index remains constant enough for practical purposes over at least five months, as shown by the following values of n_D corrected for temperature.

Initial Values	2.050	2.000	1.950	1.900	1.850	1.800
Three Months	2.050	2.001	1.948	1.897	1.850	1.802
6. 5 Months	2.050	2.000	1.949	1.898	1.850	1.801
9. 5 Months	2.049	2.000	1.950	1.898	1.851	1.802

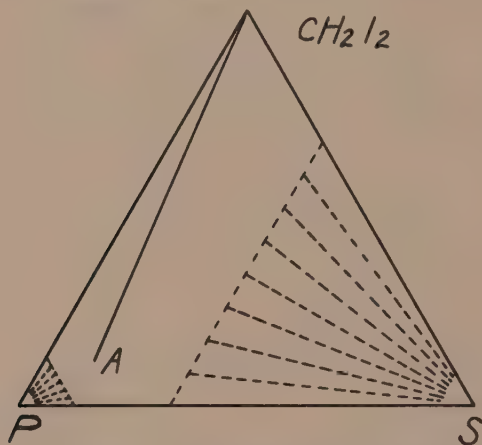


FIG. 2. System P-S-CH₂I₂, 25° isotherm, schematic.

The stability of the liquids on storage without a water layer has not been determined, it could hardly be less than what is indicated by the foregoing. Under water the liquids slowly evolve H₂S gas, as shown by the smell. The 2.06 liquid at times deposits phosphorus crystals, but these redissolve with slight warming. If initially turbid the liquids tend to clarify themselves on standing, small amounts of solids settling to the water/liquid interface.

A few hours' exposure to direct sunlight spoils the liquids by inducing an irreversible reaction between phosphorus and methylene iodide with separation of solid products. The decomposition is hastened by the presence of water. The thermal reaction between these two substances is less marked, since they may be heated together under water for several hours at 80° with only slight resulting turbidity.

If left exposed on a compact surface like metal or glass the liquids do not take fire; but porous material like paper or cloth regularly takes fire after an interval, presumably due to volatilization of methylene iodide.

Method of Use. The liquids are transferred from bottle to object glass by means of a small pipette, the film of water is removed by touching

with a strip of filter paper, the latter is discarded under water. After immersion the solid is examined in the usual way under a cover slip. Used slides are discarded under water. Carbon disulfide may be used as a solvent for the liquids, with due caution since it is itself volatile and highly inflammable.

Advantages. Phosphorus is inexpensive and readily available. The liquids are suitable for optical examination of low melting or unstable materials with which immersion melts cannot be used, for example many artificial crystals. Also they are more convenient and more accurate to use than the melts. In comparison with arsenic bromide-arsenic sulfide-methylene iodide liquids, the phosphorus liquids are more stable and in at least some cases less reactive with solids under examination.

Organic compounds containing unsaturated ring systems usually have one or two principal refractive indices above 1.80, these indices corresponding to vibration directions in the plane of the ring. The phosphorus liquids have been found to facilitate the examination of such materials.

SUMMARY

This article describes a set of immersion liquids for the refractive index range $n_D = 1.78-2.06$, made up of the components phosphorus, sulfur and methylene iodide. From five months' experience with the liquids it is concluded that they are practically stable and safe to use with proper precautions.

ACKNOWLEDGMENT

A search for high index liquids was undertaken at the suggestion of Professor E. S. Larsen, and the experimental work was made possible through the hospitality of Professor Charles Palache and the coöperation of Mr. Harry Berman of the Department of Mineralogy, Harvard University. To these men the writer offers his best thanks.

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- ⁵ Data of Madan and Damien, cited by Mellor, *loc. cit.*, p. 763. Originals not consulted.

CRYSTALLOGRAPHY OF AMMONIUM MOLYBDO-DITELLURATE

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AND

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SUMMARY

Ammonium molybdo-ditellurate, $3(\text{NH}_4)_2\text{O} \cdot 2\text{TeO}_3 \cdot 6\text{MoO}_3 \cdot 10\text{H}_2\text{O}$, is monoclinic, probably holohedral. $a:b:c = 1.8912:1:1.0731$, $\beta = 115^\circ 38'$. The crystals are usually tabular on (001) and have one distinct cleavage (100). $H = 2\frac{1}{2}$. $G = 2.22$. Biaxial negative, $\alpha = b$, $\gamma:c = 58\frac{1}{2}^\circ$ in the acute angle. Refractive indices: $n_\alpha = 1.684$, $n_\beta = 1.727$, $n_\gamma = 1.741$. Homeomorphous with a number of substances, although with different habit. The Barker angles are given, and also the optical characters of recrystallization products on a glass slip.

ACKNOWLEDGMENTS

Two new ammonium molybdo-tellurates have been prepared by V. M. Meloche and Willard Woodstock.¹ One of these salts has the formula $3(\text{NH}_4)_2\text{O} \cdot \text{TeO}_3 \cdot 6\text{MoO}_3 \cdot 7\text{H}_2\text{O}$. We have described its crystallographic characters elsewhere;² it belongs to the orthorhombic system and is homeomorphous with potassium molybdo-tellurate, to which H. F. Hansen³ assigned the formula $3\text{K}_2\text{O} \cdot \text{TeO}_3 \cdot 6\text{MoO}_3 \cdot 8\text{H}_2\text{O}$.

The other ammonium salt is a ditellurate $3(\text{NH}_4)_2\text{O} \cdot 2\text{TeO}_3 \cdot 6\text{MoO}_3 \cdot 10\text{H}_2\text{O}$. Its crystallography is the object of the present paper. We wish to extend our sincere thanks to Professor Meloche and Dr. Woodstock for sending us the necessary material.

INTRODUCTION

Beautiful crystals of ammonium molybdo-ditellurate can be obtained by recrystallization from an aqueous solution. They average 2 to 5 millimeters in the greatest dimension, are well developed, colorless, clear and transparent with splendid vitreous luster. The faces are plane and have good reflecting power, permitting very accurate goniometric measurements.

Hardness = $2\frac{1}{2}$. Specific gravity = 2.22 ± 0.05 .

On account of the solubility of the substance in water the specific gravity was determined in ether and the value corrected accordingly.

FORM

The substance crystallizes in the monoclinic system (probably prismatic class, $C_{2h} = 2/m$).

¹ *Jour. Am. Chem. Soc.*, vol. 51, p. 171, 1929.

² *Proc. Nat. Acad. Sci.*, vol. 20, pp. 327-35, 1934.

³ Unpublished thesis, University of Wisconsin, 1929.

Axial elements: $a:b:c = 1.8912:1:1.0731$; $\beta = 115^\circ 38'$. These elements correctly define the Haüy-Bravais lattice, provided the unit cell is base-centered (octahedral mode of the monoclinic lattice).

Seven crystal forms were observed. They may be listed as follows: $p\{001\}$, $m\{110\}$, $h^1\{100\}$, $a^{1/2}\{20\bar{1}\}$, $b^{1/2}\{11\bar{1}\}$, $a^1\{10\bar{1}\}$, and $b^{1/4}\{22\bar{1}\}$, in the order of decreasing importance (based on their observed sizes and frequencies).

All seven forms are present on most crystals. A few did not show the form $a^1\{10\bar{1}\}$. On all crystals examined, $b^{1/4}\{22\bar{1}\}$ occurs as very narrow truncations ("line-faces"). The forms are shown on the stereographic projection (Fig. 1).

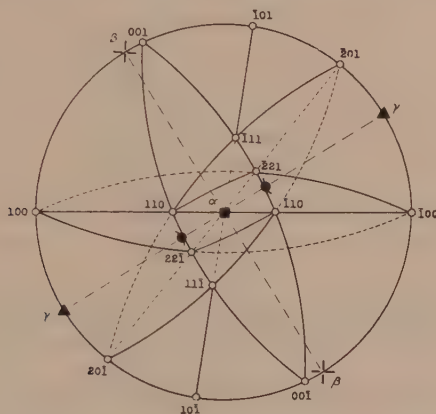


FIG. 1. Stereographic projection of ammonium molybdo-ditellurate.

Zone-circles drawn in heavy lines for edges observed on crystals with prevalent habit; dashed zone-circles for non-observed edges.

Cleavage. Only one distinct cleavage, $h^1\{100\}$, was observed. It accounts for the striae seen on $p\{001\}$, parallel to the edge $ph^1[010]$.

Habit. About 50 per cent. of the crystals obtained in any one crop exhibit a typical tabular habit on $p\{001\}$. The general appearance is that of thin plates, roughly rhombic in shape, with beveled edges. The "bevel" is the result of the intersection of a face of $m\{110\}$ with a face of $b^{1/2}\{11\bar{1}\}$. The acute angles of the "rhomb" are cut off by faces of $h^1\{100\}$ and $a^{1/2}\{20\bar{1}\}$. The other forms are minor truncations. This prevalent habit is illustrated in Fig. 2.

A few crystals show less flattening on $p\{001\}$ and are thick tabular to short prismatic. Rarer still is the following development which can be termed pseudo-trigonal pyramidal. The crystal lies on $a^{1/2}(20\bar{1})$; its apex being truncated by a small triangular face $a^{1/2}(20\bar{1})$. The combined forms $p\{001\}$, $m\{110\}$, on the one hand and $h^1\{100\}$, $b^{1/2}\{11\bar{1}\}$, on the other,

very roughly resemble rhombohedra. In this unusual habit, the face $a^{1/2}(\bar{2}01)$ is the largest of all.

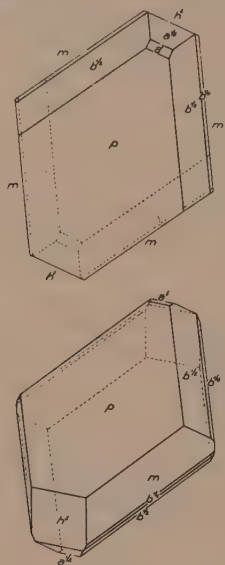


FIG. 2. Plan and orthographic projection (26° rotation, 25° tilt).
A common habit of ammonium molybdo-ditellurate.

MEASUREMENTS AND CALCULATIONS

Six crystals have been measured on the one-circle Wollaston goniometer. The signal images were good and the series of readings satisfac-

TABLE 1. COMPARISON OF MEASURED AND CALCULATED ANGLES

Number of readings	Probable error	Angle		Measured (mean)	Computed	Diff.
		Lévy	Miller			
8	7'	$h^1 a^{1/2}$	$100 \wedge 20\bar{1}$	*52° 5'	—	—
10	6'	$p h^1$	$001 \wedge 100$	*64° 22'	—	—
12	8'	$p a^{1/2}$	$001 \wedge \bar{2}01$	63° 36'	63° 33'	3'
3	—	$a^1 a^{1/2}$	$\bar{1}01 \wedge \bar{2}01$	29° 28'	29° 25'	3'
23	7'	$h^1 m$	$100 \wedge 110$	59° 37'	59° 36'	1'
6	5'	$m m$	$110 \wedge \bar{1}10$	*60° 47'	—	—
19	15'	$p m$	$001 \wedge 110$	77° 22'	77° 21'	1'
20	11'	$p b^{1/2}$	$001 \wedge \bar{1}11$	55° 25'	55° 25'	0'
14	6'	$b^{1/2}b^{1/4}$	$\bar{1}11 \wedge \bar{2}21$	21° 31'	21° 29'	2'
24	12'	$b^{1/2}m$	$\bar{1}11 \wedge \bar{1}10$	47° 17'	47° 13'	4'
15	23'	$a^{1/2}b^{1/2}$	$\bar{2}01 \wedge \bar{1}11$	53° 38'	53° 19'	19'
15	16'	$a^{1/2}m$	$\bar{2}01 \wedge \bar{1}10$	71° 59'	71° 53'	6'

tory. Calculations were made by means of spherical trigonometry from three angles, chosen as fundamental (see Table 1). The choice of the fundamental angles was guided by the probable error computed for each series of measurements. The agreement between mean measured angles and calculated angles is close; the difference between the two values is 4' or less in seven cases out of ten; it is always much smaller than the computed probable error.

LAW OF BRAVAIS

The sequence of reticular planes, listed according to decreasing reticular density (or increasing reticular area), in the base-centered lattice defined by our axial elements, is given in Table 2.

Table 2

Form		S ²	The agreement with the observed importance of the various forms is quite satisfactory:
<i>p</i>	001	22	(1) <i>p</i> {001} dominant, conditions the tabular habit of the crystal.
<i>m</i>	110	27.5	(2) <i>m</i> {110} and <i>h</i> ¹ {100} about equally important; <i>m</i> the one prism which is always well developed; <i>h</i> ¹ the only cleavage.
<i>h</i> ¹	100		
<i>a</i> ^{1/2}	20 $\bar{1}$	28.5	(3) <i>a</i> ^{1/2} {20 $\bar{1}$ } always present, next in size.
<i>b</i> ^{1/2}	11 $\bar{1}$	38.5	(4) <i>b</i> ^{1/2} {11 $\bar{1}$ } shows fairly narrow faces, not all of which are equally developed.
	111	60	(5) <i>a</i> ¹ {10 $\bar{1}$ }, small on all crystals, absent on a few.
	201	71	
<i>a</i> ¹	10 $\bar{1}$	72.5	(6) <i>b</i> ^{1/4} {22 $\bar{1}$ }, line-faces only.
	31 $\bar{1}$	73	
	010	81	
	310	83	
	40 $\bar{1}$	91	
	11 $\bar{2}$	93	
	02 $\bar{1}$	103	
	31 $\bar{2}$	106	
<i>b</i> ^{1/4}	22 $\bar{1}$	109.5	

List of the densest
reticular planes
(S ÷ retic. area)

The influence of the motif and, perhaps, that of the conditions of crystallization are revealed by the gaps in the list (Table 2), where observed forms are indicated by their Lévy form-symbol next to their Miller indices. Still, this is another good illustration of the fact that the Haüy-Bravais lattice is the controlling factor in the development of crystal forms.

HOMEOMORPHISM

Ammonium molybdo-tellurate with ten molecules of water is homeomorphous with a number of substances: ammonium selenate, ammonium

molybdate, potassium tungstate, etc. We have reported on this homeomorphous series elsewhere⁴ in its relation to Barker's determinative scheme.⁵

From the morphological standpoint, a curious observation can be made. These various salts are crystallographically very close to one another (similar values for the interfacial angles and axial elements), so much so that their stereographic projections on $g^1\{010\}$ coincide almost exactly. Yet their habits show marked divergences. The small differences which exist, from substance to substance, between the axial elements are sufficient to alter the order of density of the reticular planes, and consequently the habit, according to the Law of Bravais.

The list of planes according to decreasing density, which was:

$$p\{001\}, m\{110\}, h^1\{100\}, a^{1/2}\{20\bar{1}\}, b^{1/2}\{11\bar{1}\}, \dots$$

for ammonium molybdo-tellurate becomes:

$$p\{001\}, h^1\{100\}, a^{1/2}\{20\bar{1}\}, m\{110\}, b^{1/2}\{11\bar{1}\}, \dots$$

for potassium tungstate, and:

$$p\{001\}, a^{1/2}\{20\bar{1}\}, m\{110\} = h^1\{100\}, b^{1/2}\{11\bar{1}\}, \dots$$

for ammonium molybdate.

The crystal habit varies accordingly. It is acicular with an elongation parallel to the edge $ph^1[010]$ in potassium tungstate, the observed forms of which⁶ follow the theoretical order exactly. The same type of habit, long prismatic parallel to $[010]$, is also found in ammonium molybdate where, however, the form $a^{1/2}\{20\bar{1}\}$ becomes much more important as can be seen on Groth's drawing.⁷

The unexpected fact that homeomorphous substances may show decidedly different habits is in agreement with the theory.

BARKER'S CLASSIFICATION ANGLES

The two form combinations observed lead to the same setting.

Transformation: Old to New: $102/010/\bar{1}00$. New to Old: $00\bar{2}/020/101$.

Forms: Old: $001 \cdot 110 \cdot 100 \cdot 20\bar{1} \cdot 11\bar{1} \cdot 22\bar{1}; 10\bar{1}$
New: $100 \cdot 11\bar{1} \cdot 10\bar{1} \cdot 00\bar{1} \cdot \bar{1}1\bar{1} \cdot 01\bar{1}; 10\bar{1}$.

Angles: $cr = 29^\circ 25'$, $ra = 34^\circ 8'$, $am = 62^\circ 40'$, $bq = 30^\circ 34'$.

Since the form $b^{1/4}\{20\bar{1}\}$ is very small, it may be missing on some crystals (although we have not found this to be the case) or, if present, it may pass unnoticed. The form $a^1\{10\bar{1}\}$ may likewise be missing. Hence

⁴ *Annales Soc. géol. Belgique*, vol. 57, B 39–52, 1933.

⁵ Barker, T. V., *Systematic Crystallography*, 115 pp., London, Thomas Murby and Co., 1930.

⁶ Groth, *Chemische Krystallographie*, vol. 2, p. 359, 1908.

⁷ Groth, *loc. cit.*, p. 358, Fig. 637.

the combination of only the largest forms must be considered as though it were an observed combination. Another entry is thus found to be necessary. It is as follows:

Transformation: Old to New = New to Old = $\bar{1}0\bar{1}/0\bar{1}0/001$.

Forms: $\frac{\text{Old: } 001 \cdot 110 \cdot 100 \cdot 20\bar{1} \cdot 11\bar{1}}{\text{New: } \bar{1}0\bar{1} \cdot \bar{1}\bar{1}0 \cdot \bar{1}00 \cdot \bar{1}0\bar{1} \cdot 0\bar{1}\bar{1}}$.

Angles: $cr = 29^\circ 25'$, $ra = 52^\circ 5'$, **$am = 59^\circ 37'$** , $bq = 43^\circ 18'$.

OPTICAL PROPERTIES

Biaxial negative. The refractive indices are as follows: $n_\alpha = 1.684$, $n_\beta = 1.727$, $n_\gamma = 1.741$, all ± 0.001 . The above values have been obtained by the immersion method, each index liquid being checked on the refractometer as it was used.

Optical orientation: α lies along the b -axis; the plane of the optic axes is thus perpendicular to $g^1\{010\}$, its trace on g^1 coincides with the obtuse bisectrix γ and makes an angle of $58\frac{1}{2}^\circ$ with the c -axis, in the acute angle. The optic normal β lies at an angle of 6° (toward the observer) with the normal to $p\{001\}$.

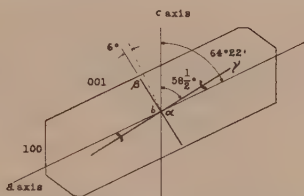


FIG. 3. Optical orientation of ammonium molybdo-ditellurate.
Cross-section parallel to (010).

Angle of the optic axes: $2V = 58^\circ$ (calculated from the indices). We could not succeed in measuring the optic angle on the universal stage, the optical orientation with respect to the crystal habit being such as to make this measurement well nigh impossible.

The optical orientation is shown on Figs. 1 and 3.

RECRYSTALLIZATION ON A GLASS SLIP

The substance can easily be recrystallized on a glass slip by letting a drop of saturated aqueous solution evaporate.

A large majority of the crystals formed are small plates, rhombic in outline, with the acute corner more or less truncated (Fig. 4). The acute angle of the rhomb is 55° , as measured on the rotating stage. The extinction is symmetrical, the direction of the long diagonal of the rhomb has positive elongation (length slow). The interference figure obtained in

$pb^{1/2} [\bar{1}\bar{1}0]: [1\bar{1}0]$. The plates consequently lie on $p\{001\}$. The positive elongation is in agreement with the optical orientation. The interference figure can be accounted for by the fact that $p\{001\}$ is almost parallel to the plane of the optic axes; the hyperbolas flash out of the field in the direction of the acute bisectrix α , as is to be expected from the theory. The section birefringence of $p\{001\}$, calculated from the indices, is 0.0568, a little smaller than the maximum birefringence ($n_\gamma - n_\alpha = 0.057$).

Other crystals obtained by recrystallization show a rectangular outline, which can be identified as $h^1\{100\}$. Still others are six-sided and elongated (see Fig. 5), with external angles of 57° , 57° , and 66° (measured on the rotating stage). In convergent light they show the interference figure of a section nearly perpendicular to one of the optic axes. In parallel light a 6° extinction angle can be measured against one of the sides. The geometrical and optical characters identify the face as $m(1\bar{1}0)$, whose normal is inclined at an angle of 16° to an optic axis. The optical characters of a face $(\bar{1}10)$ of the rhombic vertical prism $m\{110\}$, as derived from the orientation of the indicatrix, are shown on Fig. 5. The agreement with the experimental data is perfect. In Fig. 5, n_1 is greater than n_2 .

The study of the results of recrystallization on a glass slip is of great importance from the determinative viewpoint. The present substance is a good example of the amount of information that can be gathered by such technique.

A SPECTROPHOTOMETRIC STUDY OF SMOKY QUARTZ

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ABSTRACT

The absorption curve of smoky quartz was determined from 700 to 200 $m\mu$; this was compared with its absorption after decoloration by heat and exposure to radium, and with clear crystalline and fused quartz colored by the same exposure. Some fluorescence effects were noted. All showed maxima at 16,500, 20,000, 25,000, 33,000, 38,000 (wave number per cm.), with increased absorption beyond 42,000. Further irradiation in general simply increased absorption, but fused quartz showed a shift in importance of the bands, with a superposed lavender tint. The similarity in curves of originally smoky and the irradiated specimens confirms the theory of radioactive coloration.

The change in energy due to the transfer of an electron from an oxygen to a silicon ion is calculated, and possible subsequent changes due to redistribution of such electrons. These changes correspond to amounts of energy indicated by positions of absorption bands.

Clear quartz colored by exposure to radioactive action is similar in appearance to naturally colored smoky quartz; their absorption curves in the visible region were compared by Holden¹ in his study of the causes of this color. The following experiment extends the comparison to 200 $m\mu$.

EXPERIMENTAL PROCEDURE AND RESULTS

Spectrograms of several pieces of smoky quartz were taken with a Hilger E3 spectrograph, used in conjunction with a Gaertner rotating sector photometer, and as a light source a hydrogen discharge tube run by a 1 kw. transformer was used. The specimens were placed near the slit of the spectrograph, in the lower beam from the photometer.² Due to the irregular variations in absorption which occur in naturally colored specimens, a sufficiently complete series for a curve was taken on each plate, as well as a test strip without the absorbing material. Points of equal density on the standard and absorbed strips were estimated visually; the probable error of these readings was found to be less than 1%.

The absorption curves plotted from these results showed identical positions of maxima for the different specimens. The one given (Fig. 1) is from a piece cut from a deeply colored crystal from Florissant, Colorado; it was cut with plane, parallel faces, and with a thickness of .23 cm.

¹ Holden, E. F., The cause of color in smoky quartz and amethyst: *Am. Mineral.*, vol. 10, p. 203, 1925.

² Mohler, N., Ultra-violet absorption of certain minerals: *Am. Mineral.*, vol. 16, p. 300, 1931. The spectrum with the E3 spectrograph is about 8".

This specimen was decolored by heating to 300°C. for 15 minutes; then it, together with a piece of clear crystalline quartz of optical quality (thickness .47 cm.) and a piece of fused quartz (.20 cm.) cut from a drawn rod, were exposed for 92 days to the gamma rays from 100 mg. of radium. All showed the typical smoky color. Spectrograms taken at once showed fluorescence in the ultra-violet; those taken later yielded absorption curves similar to that of the naturally colored smoky quartz (Figs. 1, 2, 3).

A second exposure, to 200 mg. of radium for 140 days, was then made, part of the time to beta and gamma rays. A more intense smoky color was produced, especially in the parts affected by the beta rays; the fused quartz showed a lavender tint on the smoky background. Spectrograms were taken as before, and also with an alanine filter. As this cuts at 200 $m\mu$ and the fused quartz window of the discharge tube at 190 $m\mu$, the wave length of the fluorescence-exciting radiation was limited sufficiently to permit a rough estimate of the shift in wave length. The resulting curves are given in Figs. 1, 2, 3, 4.

The results for all of the crystalline specimens, whether naturally or artificially colored, show maxima at 16,500, 20,000, 25,000, 33,000, 38,000 (wave number per cm.) with increased absorption beyond 42,000. The similarity offers strong confirmation to the hypothesis of coloration by radioactive action.

THEORETICAL DISCUSSION

Theories proposed to explain this action^{3,4} assume a transfer of electrons to new positions as a result of radioactive bombardment, with either their subsequent return or a coagulation of ions into colloid particles. A calculation of the order of magnitude of forces involved in the first of these assumptions follows. The crystal energy due to Coulomb binding forces and a repulsive force effective at small distances is given by the equation:

$$\phi = -\frac{ze^2A}{r} + \frac{B}{r^n}$$

in which ze is the charge on an ion, r a characteristic ionic distance, A the Madelung constant which depends on the magnitude and distances of the surrounding charges (assumed 2.44), n a constant which can be calculated from compressibility data (taken as 9), B a constant which can be eliminated by the condition that at equilibrium $r=R$, the experimentally found ionic distance. To simplify the calculation of the change

³ Lind, S. C., and Bardwell, D. C., Coloring and thermophosphorescence produced in transparent minerals and gems by radium radiations: *J. Frank. Inst.*, vol. 196, p. 375, 1923.

⁴ Przibram, Color changes and luminescence due to Becquerel rays: *Zeit. Phys.*, vol. 68, p. 403, 1931.

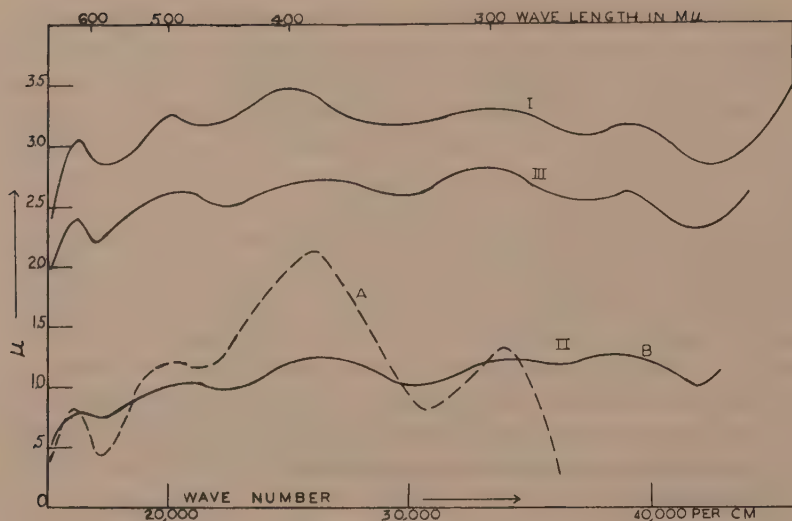


FIG. 1. Absorption curves of smoky quartz.

- I. Naturally smoky quartz.
- II. After decoloring by heat, followed by 92 days of irradiation with 100 mg. radium.
 - A. Curve determined immediately.
 - B. Curve determined 5 weeks later.
- III. After second irradiation for 140 more days, with 200 mg. radium.

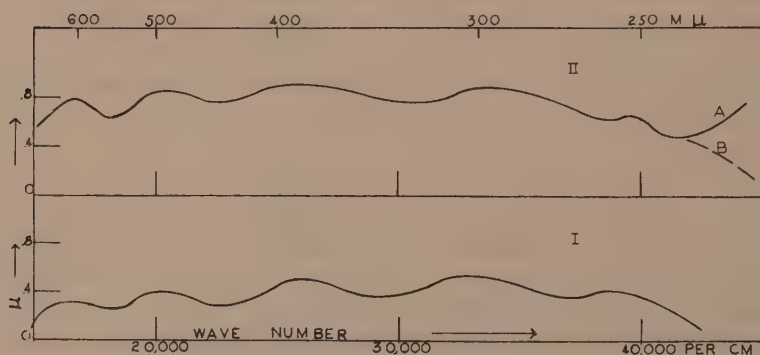


FIG. 2. Clear crystalline quartz.

- I. After first irradiation.
- II. After second irradiation.
 - A. Plates taken with alanine filter.
 - B. Plates taken without filter.

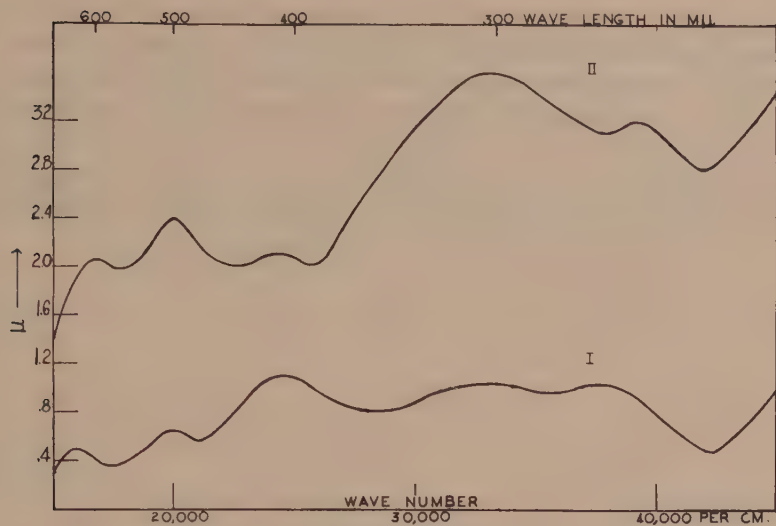


FIG. 3. Clear fused quartz.

I. After first irradiation.

II. After second irradiation.

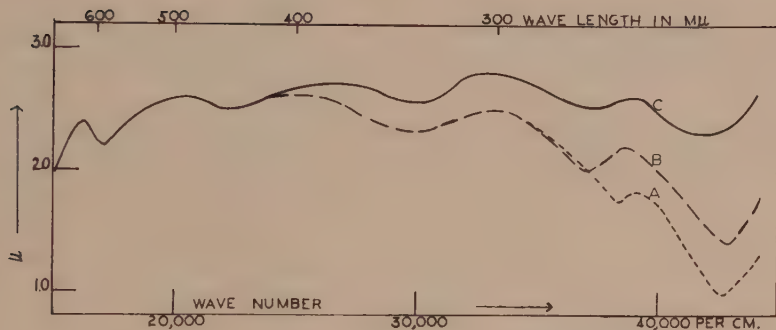


FIG. 4. Smoky quartz after second irradiation.

A. Curve taken at once without filter.

B. Curve taken at once with alanine filter.

C. Curve taken 5 days later, no filter.

introduced by a shift of one or more electrons, this may be written:

$$\phi = z e P, \text{ with } P = -2e(\sum 1/r_o - \sum 2/r_{si})(1 - 1/n).$$

For the value of r for beta quartz

$$\phi = -.889 \times 3.07 e^2 z.$$

The shift of an electron from an oxygen to a silicon ion would mean a change in z from 4 to 3; then the summation, if considered for an electrostatically neutral region, must be changed by $1/R$. For beta quartz $R=1.61$; for alpha quartz, with which we are concerned, there are two values for R , as the oxygen tetrahedron is distorted. The possible values are given in Table 1. One series of energy changes correspond to changes in z , a second series corresponds to changes with z constant. The order of

TABLE 1. ENERGY LEVELS FOR A SILICON ION IN LOW QUARTZ

A			B		
z	$\sum \frac{2}{r_{O}} - \sum \frac{4}{r_{Si}}$	$-\frac{\phi}{e^2}$	$\sum \frac{2}{r_{O}} - \sum \frac{4}{r_{Si}}$		$-\frac{\phi}{e^2}$
$4 \times .889 \times 3.07$		10.92			
$3 \times .889 \times 3.07-.61$		6.55	$3.07-.30$		7.38
$3.07-.65$		6.37	$3.07-.27$		7.46
			$3.07-.25$		7.50
$2 \times .889 \times 3.07-.61-.61$		3.29	$3.07-.61-.30$		3.84
$3.07-.61-.65$		3.22	$3.07-.61-.27$		3.89
$3.07-.65-.65$		3.14	$3.07-.61-.25$		3.92
			$3.07-.65-.30$		3.76
			$3.07-.65-.27$		3.82
			$3.07-.65-.25$		3.86
$1 \times .889 \times 3.07-.61-.61$			$3.07-.61-.61-.30$		1.38
$-.65$		1.07	$3.07-.61-.61-.27$		1.41
$3.07-.61-.65$			$3.07-.61-.61-.25$		1.42
$-.65$		1.03	$3.07-.61-.65-.30$		1.34
			$3.07-.61-.65-.27$		1.37
			$3.07-.61-.65-.25$		1.39
			$3.07-.65-.65-.30$		1.31
			$3.07-.65-.65-.27$		1.33
			$3.07-.65-.65-.25$		1.35
C			D		
$2 \times .889 \times 3.07-.30-.27$		4.44			
$3.07-.30-.25$		4.47			
$3.07-.27-.25$		4.52			
$3.07-.25-.25$		4.56			
$1 \times .889 \times 3.07-.61-.30-.27$		1.68	$3.07-.30-.27-.25$		2.00
$3.07-.61-.30-.25$		1.70	$3.07-.30-.25-.25$		2.02
$3.07-.61-.27-.25$		1.73	$3.07-.27-.25-.25$		2.05
$3.07-.61-.25-.25$		1.74			
$3.07-.65-.30-.27$		1.64			
$3.07-.65-.30-.25$		1.66			
$3.07-.65-.27-.25$		1.69			
$3.07-.65-.25-.25$		1.71			

magnitude of the first set is that of energy available in radioactive action; of the second, that of much smaller energy changes. The latter are grouped in Table 2, with their corresponding wave numbers, and the wave numbers of the regions of principal absorption.

TABLE 2

In A are grouped differences calculated from Table 1 for z constant, and shifts of a single electron only. In B are the wave numbers corresponding to these energies.

In C are the absorption maxima found experimentally.

A	B	C
Energy changes	Wave number per cm.	Wave number of absorption maxima
.50-1.13 $-\frac{\phi}{e^2}$	58.0 -131×10^3	
not continuous		
.40-.46	46.4 -53.4	Above 43×10^3
.38-.22	44.1 -25.6	24-42, with maxima at 25, 34, 38
.18	20.9	20.5
.12	13.9	16.5
.01-.08	1.16- 9.29	Fluorescence shifts between 4.3 and 12

The hypothesis involved in these comparisons is that the initial disturbance caused by the radioactive action may be followed by rearrangements of electrons if the requisite energy is supplied. The results given, since corrections for readjustment in position of the ions are neglected, are of value only in indicating an order of magnitude. The agreement seems sufficient, however, to indicate that a further assumption of a coagulation of colloid particles is unnecessary to account for the color of smoky quartz.

NOTES AND NEWS

BERTRANDITE AND EPISTILBITE FROM BEDFORD, NEW YORK

FREDERICK H. POUGH, *American Museum of Natural History,
New York City.*

Bertrandite, one of the rarer beryllium minerals and found at but few American localities, is always of interest. Several specimens were collected in May 1935, at Baylis Quarry, Bedford, N. Y., by Mr. James G. Manchester of Scarsdale, who submitted two of them to the American Museum of Natural History for identification, and announced the discovery at the January meeting of the New York Mineralogical Club. The specimens were collected from a pile of beryl fragments near the entrance to the quarry, which were taken out during recent widening operations.

The specimens examined are similar in appearance, with a matrix composed of a greenish-yellow beryl, upon the surfaces of which are the crystals of the two minerals. The beryl is not strongly etched and in this respect the occurrence differs greatly from that of Pisek, Bohemia, where only shreds of the former beryl crystals remain, with the bertrandite occupying the solution cavities. The surfaces which are now coated with the secondary crystals appear to be old interference faces of the beryl, but the etching has been sufficient to give them a lustrous finish. Directly in contact with the beryl is a layer of minute colorless crystals of bertrandite, and covering these, almost completely on one of the specimens, are subparallel bundles of yellowish to white crystals, 3 or 4 mm. long.

The bundles resemble stilbite in appearance, but the individuals are somewhat more platy and less equidimensional than is usual with that mineral. Optical tests showed the mineral to be epistilbite, with indices slightly higher than those of stilbite, but agreeing very well with those of the former mineral. Radiating clusters of stilbite needles have also been found at Bedford recently. The epistilbite bundles must be later than the bertrandite, for they cover the smaller crystals. The specimen on which the epistilbite crust is nearly continuous shows the minute plates of bertrandite in but two places, where they are revealed in gaps between the bundles. Apparently, however, bertrandite actually covers the surface beneath the later mineral.

The bertrandite layer is composed of extremely small crystals, none over 0.5 mm. long. While the crystals themselves are colorless, the crust is slightly brownish from a limonitic coating over some of the crystals. The crystals are tabular, dominated by $b(010)$ and slightly elongated in the direction of the a -axis. The unit prism and the three pinacoids were

the only forms observed. The optical properties agree perfectly with those accepted for bertrandite.

The occurrence of bertrandite and zeolites in any pegmatite is interesting from the standpoint of paragenesis and mineral sequence. Bertrandite never seems to form through ordinary weathering processes, but to be invariably the product of an hydrothermal attack upon beryl as that mineral becomes unstable in the environment of the later solutions. It has not been described as resulting from the alteration of any other beryllium mineral; beryl seems to be the sole parent mineral. Its occurrence, then, is a good indication of a complex pegmatite and a continued hydrothermal activity.

Consequently, with the addition of these minerals to the already long list of Bedford species, we may consider the deposit another of the pegmatite occurrences in which the entire sequence of mineralization, from late magmatic stages to the zeolite-forming phase, is revealed. With an intermediate period in which the bertrandite was formed before the zeolites began to crystallize, we can visualize a more or less continuous process of mineral formation and alteration.

URANINITE FROM HOTTAH LAKE

FRANK H. BRUNER.

Through the courtesy of Dr. A. C. Lane, a two kilogram sample of pitchblende from the Hottah Lake deposit was obtained from the Canadian Bureau of Mines.

The sample received had been crushed and coarsely ground. The mineral was subjected to a complete analysis, the results of which are given in the following table:

U ₃ O ₈	51.45%
Fe ₂ O ₃	41.51
Pb	2.31
SiO ₂	2.75
Al ₂ O ₃	1.12
CaO	1.01
MgO	Trace
Mn	Present
S	0.14
CO ₂	0.42
Total	100.71

Chemical and electroscopic tests failed to show any thorium; this absence has also been substantiated by other reports.

The lead and uranium were determined in a very careful manner. The results of these determinations gave a lead-uranium ratio of 0.0529,

which gives the approximate age as 387 million years.¹ The value of this ratio checks the ratio of 0.0530, found for the Beaverlodge uraninite.²

Thallium formate was chosen as the best heavy liquid to be used in a gravity separation. No satisfactory separation was obtained by this method. However, it was noticed that most of the finer brown portion of the ore that had been ground to 40 mesh fineness could be washed out with water by differential sedimentation. After washing, about eighty-six per cent of the brownish ore was left as a uniform black ore. A sample of this black residue was used for a second determination of the lead-uranium ratio. Practically all the lead was found in this black residue while it was only slightly enriched in uranium. The ratio in this second case, 0.0584, was slightly higher than in the original sample. This substantiates the belief that weathering is more selective to uranium than to lead.³

Using the acton method, the actinium-uranium ratio of this mineral was constant in accord with the seven minerals previously reported.⁴

A successful magnetic separation has been accomplished on roasted ore, and the determination of the lead-uranium ratio of the non-magnetic portion is under way at the present time.

In the future the Ac-U ratio and Pa-U ratio will be established by absolute methods.

¹ Kirsch, G., *Geologie und Radioaktivität*, p. 128, 1928.

² Private communication from W. R. McClelland of the Canadian Bureau of Mines.

³ Alter, C. M., and Kipp, E. M., *Science*, vol. 82, No. 2133, pp. 464-66, Nov. 15, 1935.

⁴ Bruner, F. H., and Schlundt, H., *Jour. Phy. Chem.*, vol. 38, No. 9, pp. 1183-88, 1934

LOCALITY FOR OPALIZED SPHERULES

A. E. ALEXANDER, *Buffalo Museum of Science*.

In answer to the writer's query, Mr. R. C. Vance of Rochester, N. Y., states that the opalized spherules mentioned in the August issue of the *American Mineralogist*¹ were obtained from Mt. Tate, Etchu Province, Japan. Specimens in his possession were compared with those described and proved to be identical.

¹ Alexander, A. E., Opalized spherules from Utah?, *Am. Mineral.*, vol. 20, pp. 602-3, 1935.

BOOK REVIEW

LEHRBUCH DER MINERALOGIE, W. SCHMIDT AND E. BAIER. 320 pages, 214 illustrations, one colored plate. Gebrüder Bornträger, *Berlin*, 1935. Price RM 14.

This book embodies a great deal of what might be called the modern trend in mineralogy. In spite of its limited size a reader will find in this text short discussions on almost every mineralogical topic. The authors have, however, omitted a systematic treatment of crystal forms because, as they say, the subject is of such scope that it should be treated separately.

The book follows Niggli's "Lehrbuch der Mineralogie" rather closely, although the space given to the various chapters is allotted rather unevenly. The first 56 pages treat of the geometry of crystals with special emphasis on structure. A table of atomic and ionic radii is a welcome addition to this part. The next chapter is entitled *Kristallphysik* but it includes only optics with the exception of a few paragraphs on electrical and heat conductivity. These 40 pages presuppose a considerable knowledge of mathematics and physics. A beginner in optical mineralogy would find them too difficult. A beautiful colored plate of interference colors and interference figures is included. About 15 pages deal with deformation, cleavage, hardness and density of minerals. Much that one finds in the ordinary textbook has been entirely omitted in this chapter. On the other hand, one finds in the 30-page chapter on mineral chemistry very interesting discussions on the polymorphism of iron and on the principles of flotation.

The second half of the book is devoted to descriptive mineralogy. The minerals, wherever possible, are classified according to their structures, though the large divisions are necessarily chemical. The authors instead of following the usual rather dry recitation of properties of each mineral have adopted a narrative style which should be more interesting to the student. It is, however, unsuitable for a systematic course on descriptive mineralogy and almost impossible as a reference work. Occasionally overemphasis is given to certain minerals as, for example, cubanite, chalcopyrrhotite and vallerite. The student may easily receive the impression that such minerals are easily determined megascopically in copper ores. The discussion on ice occupies one page, while that of iron, aluminum and manganese oxide minerals is treated as a geological and metallurgical chapter. Since the book is intended primarily for chemists and engineers, this is not only permissible but desirable. The chemistry of the chlorides and sulphates, with special reference to Stassfurt, is treated in great detail. An alphabetical index completes the book.

On the whole the authors have succeeded to a remarkable degree in producing a text which holds the reader's interest to the last, an accomplishment not common in texts on mineralogy. The binding and paper are of fine quality. The figures and illustrations are excellent. Except for a very few typographical errors, the book appears to be practically flawless.

J. W. GRUNER

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, January 2, 1916

President H. W. Arndt presided at a stated meeting, 29 members and 16 visitors attending. Dr. Joseph L. Gillson spoke on the "Minerals of the Pioche, Nevada, silver mining region." He described the occurrence of jarosite, plumbojarosite, hydrozincite, magnesite, willemite crystals ($\frac{1}{2}$ to 1 mm.), vanadinite, rhodonite with green epidote, cordierite, ludwigite, and fluorborite.

Charles R. Toothaker read an article on jade from the United States Commerce Reports, giving the sources, basis of valuing, methods of marketing, and a description of the world's finest piece of jade in the form of a bowl. Edgar T. Wherry reviewed the main events of the annual meetings of the Mineralogical Society of America held in New York City in December. Louis Moyd reported on a trip to Paterson, Prospect Park and Great Notch, New Jersey. J. Kenneth Fisher reported $1\frac{1}{4}$ inch zincite crystals being obtained recently at Franklin Furnace, New Jersey.

W. H. FLACK, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

MINERALOGICAL SOCIETY, *January 30*, PROF. P. G. H. BOSWELL, Vice-President, in the chair.

(1) *The Morven meteorite, an aerolite from South Canterbury, New Zealand*. By Mr. C. O. HUTTON (communicated by Professor W. N. Benson).

This stone, which weighed about 7100 grams before being broken, was found in 1925 during ploughing, $4\frac{1}{2}$ miles south of Morven railway station. There is no local record of the fall, and the nature of the weathered crust suggests that it may have been in the soil for a long time. Micro-sections are described and detailed chemical analyses were made of different fractions. The stone is classed as a veined and brecciated bronzite-olivine-chondrite containing 13.18% of metallic nickel-iron. It is the fourth meteorite to be recorded from New Zealand.

(2) *Eulysites and related rock-types from Loch Duich, Ross-shire*. By Professor C. E. TILLEY.

Rocks of eulysitic facies referred to a sedimentary origin are recorded among paragneisses involved in the Lewisian near Loch Duich. They include varieties rich in manganefayalite, hedenbergite, iron-hypersthene, and garnet, and are associated with grünerite-garnet-magnetite rocks of related origin.

(3) *Gold and silver in the crystalline rocks of the Malvern Hills*. By Professor A. BRAMMAL and Mr. DAVID L. DOWIE.

Gold (traces up to 3 dwts./ton) and silver (traces up to 42 dwts./ton) are indicated by assay results for over 100 samples of mapped rock-types and their constituent minerals. The highest values are associated with a pneumatolytic phase of the "latest" granites. Assay data and spectrographs afford some check on the interpretation of certain mixed rocks, notably dioritic and appinitic types.

(4) *The rôle of Al-atoms in the two reaction series*. By Professor A. BRAMMALL.

X-ray work suggests that the break in the enstatite-diopside series and also that between the amphiboles and the basic micas are related to the continuous reaction (NaSi)-(CaAl) in the plagioclase series. The rôle of Al-atoms in the two series is reciprocal.

(5) *On the magnetite-plagioclase rocks of Magnet Heights, Bushveld, Transvaal*. By Dr. A. K. WELLS.

The paper describes the petrographic characters of the unique magnetite-plagioclase rocks which occur associated with norite and anorthosite at a relatively high level in the Bushveld complex. The bearing of the petrography upon the problem of the genesis of the rocks is discussed.

NEW MINERAL NAMES

Khibinite

I. K. KHAZANOVICH, Lovchorrite of the Khibia Tundra: *Razvedka Nedr* (Subterranean Prospecting), vol. 4, No. 1, p. 28, 1935. *Chem. Abstr.*, vol. 29, No. 14, p. 4702, 1935.

A mineral related to Lovchorrite is called Khibinite.

Nuolate

LAURI LOKKA, Über Wiikite: *Bull. Comm. Geol. Finlande*, No. 82, p. 21, 1928.

A name given to a mixture of two minerals (1) amorphous transparent and (2) crystal-line opaque, differing from wiikite in being richer in thorium and free from uranium, consisting essentially of tantalates, and columbates of rare-earths. From Nuolainniemi, Finland. Not proposed as a mineral species name.

Iron Strigovite

SVEN PALMQUIST, Geochemical studies on the iron bearing Liassic Series in southern Sweden: *Meddelanden. Lunds Geol. Mineral. Inst.*, No. 60, p. 167, 1935. A term proposed for the green iron silicate from siderite sandstones of Rödingeberg, S. E. Scania, Sweden, probably $2(\text{Fe}, \text{Mg})\text{O} \cdot (\text{FeAl})_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$; the iron analogue of strigovite.

W. F. FOSHAG

Bacalite

JOHN BUDDHUE, Mexican Amber: *Rocks and Minerals*, vol. 10, pp. 170-171, 1935.

A fine yellow amber from Baja California, similar to succinite but differing from it in its relative insolubility in ether, alcohol, chloroform, carbon tetrachloride, carbon disulfide and oil of turpentine. The name is derived from an abbreviation of the locality, Baja California.

W. F. F.

Hydroxylapatite

CONRAD BURRI, JOHANN JAKOB, ROBERT L. PARKER AND HUGO STRUNZ, Über Hydroxylapatit von der Kemmlen bei Hospenthal, (Kt. Uri): *Schweiz. Min. Petr. Mitt.*, vol. 15, No. 2, pp. 327-339, 1935.

CHEMICAL PROPERTIES: A hydroxy-phosphate of calcium, $9\text{CaO} \cdot 3\text{P}_2\text{O}_5 \cdot \text{CaO} \cdot \text{H}_2\text{O}$. Analysis: CaO 55.47, MnO 0.06, P_2O_5 42.19, $\text{H}_2\text{O}+$ 1.73, $\text{H}_2\text{O}-$ 0.00, Insol. 0.60. Sum 100.05. Chlorine, fluorine and carbon dioxide are not present.

CRYSTALLOGRAPHICAL PROPERTIES: In rough, hexagonal crystals. $a = 9.42 \text{ \AA}$, $c = 6.935 \text{ \AA}$, $c = 0.736$.

PHYSICAL AND OPTICAL PROPERTIES: Color, yellowish to greenish. Cleavage (1010), fairly good, basal cleavage incomplete. $G = 3.076$.

Completely uniaxial, negative. $\omega_D = 1.6452$, $\epsilon_D = 1.6413$ (by prism method).

OCCURRENCE: Found intimately associated with talc in the serpentine-talc quarries at Kemmlen, Hospenthal, Canton Uri, Switzerland.

DISCUSSION: [Frequently mentioned as a hypothetical member of the apatite group (See W. T. Schaller, *Bull. U. S. Geol. Surv.*, No. 509, p. 100, 1912). This, however, seems to be the first authentic occurrence of this mineral in a relatively pure state. Abstr.]

W. F. F.

Aidyrlite

M. N. GODLEVSKY, Aidyrlite, New Mineral: *Mem. Soc. Russ. Min.*, 2d Ser., vol. 63, pp. 338-345, 1934. (Russian with Germany summary.)

NAME: From the locality Aidyrlite.

CHEMICAL COMPOSITION: A hydrous silicate of nickel and aluminum, $2\text{NiO} \cdot 2\text{Al}_2\text{O}_3 \cdot 3\text{SiO}_2 \cdot 7\frac{1}{2}\text{H}_2\text{O}$. Analysis: SiO_2 25.15, TiO_2 none, Al_2O_3 28.75, Fe_2O_3 0.06, Cr_2O_3 0.09, FeO *n.d.*, MnO none, NiO 17.59, CoO 0.13; CuO 1.52, CaO 0.53, MgO 0.39, $(\text{K}_2, \text{Na}_2)$ 0.10, $\text{H}_2\text{O}(+)$ 19.07, $\text{H}_2\text{O}(-)$ 5.98, P_2O_5 0.03; sum 99.40.

PHYSICAL AND OPTICAL PROPERTIES: Color, turquoise blue; luster dull; fracture conchoidal; brittle. Hd. about 2.5. Isotropic or weakly birefracting. $n = 1.533\text{--}1.545$, but in some cases may fall to 1.509 or reach 1.573.

OCCURRENCE: Found in small veins cutting limestone at the nickel ore deposits of Aidryr, near Kvarken, Govt. of Orenburg, Eastern Urals.

W. F. F.

Blockite

ROBERT HERZENBERG AND DIEDRICH AHLFELD, Blockite, ein neues Selenerz aus Bolivien (Vorläufige Mitteilung): *Centr. Min.*, Ab. A, No. 9, pp. 277–279, 1935.

NAME: In honor of Hans Block, mining engineer of Colquechaca.

CHEMICAL PROPERTIES: A selenide of nickel and copper: $(\text{NiCu})\text{Se}_2$. Analysis: Ag 1.73, Pt. metals 0.022, Hg 1.95, Pb 0.35, Cu 6.70, Fe 1.29, Co 2.45, Ni 14.09, Se 69.72, insol. 1.28; sum 99.58.

PHYSICAL PROPERTIES: Color, dark gray, somewhat bluish; streak black. Hd. 2.5. G. 6.03–6.06.

OCCURRENCE: Found in limonite and siderite veins near the headwaters of the Sillacruz River, E. N. E. of Colquechaca, Bolivia. Associated with pyrite, chalcopyrite and barite, also naumannite (?) and altered to ahlfeldite (in raspberry to brownish red crystals and white needles of selenolite (?).

W. F. F.

Trieuite

L. DE LEENHEER, Trieuïet, een nieuw Kobalt mineraal: *Natuurwetenschappelijk Tijdschrift, Gent*, vol. 17, pp. 91–95, 1935.

NAME: In honor of the engineer Robert du Trieu de Terdonck, chief geologist of the Union Minière du Haut Katanga.

CHEMICAL PROPERTIES: $2\text{Co}_2\text{O}_3 \cdot \text{CuO} \cdot 6\text{H}_2\text{O}$. This formula was arrived at from an analysis of contaminated material on the assumption that all CO_2 in the analysis belonged to malachite (7%) and all SiO_2 to chrysocolla (over 4%).

CRYSTALLOGRAPHICAL PROPERTIES: Not crystallized, colloidal. Powder diffraction pattern shows no lines.

PHYSICAL AND OPTICAL PROPERTIES: Color, black. Hd. 3.5. G. 3.128. Refractive index 1.85.

OCCURRENCE: Found intimately associated with malachite and chrysocolla in the "Star of Congo" mine near Elisabethville, Katanga.

REMARKS: Due to the impure character of the material some question might be raised as to its validity as a new mineral species. A. Schoep, who previously examined the material, gave the formula $3\text{Co}_2\text{O}_3 \cdot \text{CoO} \cdot \text{CuO} \cdot 7\text{H}_2\text{O}$. Leenheer, using a new method for determining cobalt, indicates all the cobalt in the trivalent form.

ADOLF PABST

Amarillite

H. UNGEMACH: Sur certains minéraux sulfatés du Chili, *Bull. Soc. Franc. Min.*, 58, Nos., 3–4, pp. 200–202, 1935.

NAME: Not stated but presumably from the locality Tierra Amarilla.

CHEMICAL PROPERTIES: A hydrous sulfate of soda and iron: $\text{Na}_2\text{O} \cdot \text{Fe}_2\text{O}_3 \cdot 4\text{SO}_3 \cdot 12\text{H}_2\text{O}$. Analyses: Na_2O 7.14, Fe_2O_3 21.39, SO_3 43.59, H_2O 28.45. Sum 100.57. Easily soluble in water.

CRYSTALLOGRAPHICAL PROPERTIES: Monoclinic; habit equidimensional or tabular to the base. Rich in faces. $a:b:c=0.7757:1:1.1482$. $\beta=84^\circ 23'$. $(100):(110)=37^\circ 40'$; $(001):(\bar{1}01)=59^\circ 52'$. 18 forms. Parallel growths observed.

PHYSICAL AND OPTICAL PROPERTIES: Color pale yellow with a tinge of green. Luster vitreous inclining to adamantine. Hd. less than 3. $G=2.194\text{--}2.197$. Taste astringent. Cleavage good. Fracture conchoidal.

OCCURRENCE: As veins in massive coquimbite and in cavities in coquimbite. Also disseminated in siliceous rock at Tierra Amarilla, Chile.

W. F. F.

Leucoglaucite

Ibid., pp. 203–209.

NAME: Presumably in reference to its pale blue color.

CHEMICAL PROPERTIES: A hydrous ferric sulfate: $\text{Fe}_2\text{O}_3 \cdot 4\text{SO}_3 \cdot 5\text{H}_2\text{O}$. Analysis: Fe_2O_3 28.06, SO_3 56.97, H_2O 15.02. Sum 100.05.

CRYSTALLOGRAPHICAL PROPERTIES: Hexagonal. Habit prismatic. $c=0.5589$. $(10\bar{1}1):(\bar{0}1\bar{1}1)=31^\circ 28'$.

PHYSICAL AND OPTICAL PROPERTIES: Color very pale bluish green, isolated crystals, colorless. Cleavage prismatic, good.

OCCURRENCE: Found in nests in coquimbite, associated with copiapite, quenstedtite, roemerite, more rarely with chalcantite and amarillite at Tierra Amarilla, Chile.

W. F. F.

"Pseudo-Copiapite"

Ibid., pp. 152–158.

A named proposed for an "aberrant" variety of copiapite, showing slight crystallographic differences from normal copiapite.

Pseudocopiapite: $a:b:c=0.3005:1:0.72915$, $\alpha=98^\circ 4'$, $\beta=89^\circ 48'$, $\gamma=102^\circ 31'$. Copiapite $a:b:c=0.3010:1:0.7295$. $\alpha=99^\circ 46'$, $\beta=90^\circ 30'$, $\gamma=104^\circ 21'$.

W. F. F.

REPORT OF THE AUDITING COMMITTEE

The Auditing Committee has examined and verified the accounts and report of the Treasurer for the fiscal year ending November 30, 1935. The securities listed in the Treasurer's report are in the safety deposit box in the vaults of the American Security and Trust Company of Washington, D. C. All future coupons on the bonds are intact and attached to these securities. Four certificates of the Trenton Mortgage and Title Guaranty Company of a total par value of \$4,000 are registered both for principal and interest. The Committee also certifies that \$300.00, in U. S. Postal Savings Bonds, laid aside for the Roebbling Medal Fund is in the safety deposit box with the above securities.

Respectfully submitted,

W. S. BURBANK

Chairman, Auditing Committee

J. B. MERTIE, Jr.

J. F. SCHAIRES

PROPOSED CONSTITUTIONAL AMENDMENT

At the recent New York meeting of the Council of the *Mineralogical Society of America*, preliminary approval was given to the following proposed constitutional amendment to be submitted to the Society for approval. The purpose of the amendment is to enable the Society to elect directly as *fellows* outstanding scientists from related scientific Societies without the necessity of requiring a preliminary *membership*.

"Outstanding scientists of recognized scientific accomplishments in the field of Mineralogy, Petrography, Crystallography, and allied sciences, who are members of other scientific societies in the field of Geology, such as the Geological Society of America, Society of Economic Geologists, American Institute of Mining and Metallurgical Engineers, the American Association of Petroleum Geologists, and other similar scientific societies, may be nominated for *fellowship* in the Society upon recommendation of the Council."

This amendment is to be submitted to the fellowship of the Society for approval within the three months' period specified by the constitution.

Respectfully submitted,

PAUL F. KERR, *Secretary*

Mineralogical Society of America

Dr. N. L. Bowen of the Geophysical Laboratory has been elected an Honorary Fellow of the recently organized Indian Academy of Sciences. The other Americans honored are Professors A. H. Compton, Harvey Cushing, R. A. Millikan, G. N. Lewis and D. D. Van Slyke.